The PreCam Survey: Status and Results

Kyler Kuehn, Argonne National Laboratory

DARK ENERGY SURVEY

RASICAM
(mid-2011)

UM-A Curtis-Schmidt

Blanco 4m

Courtesy: NOAO/AURA/NSF

PreCam Survey: a quick, bright *grizy* survey in the DES footprint using a 4kx4k camera composed of DECam CCDs – the "PreCam" – mounted on the University of Michigan Dept. of Astronomy's Curtis-Schmidt Telescope at CTIO.
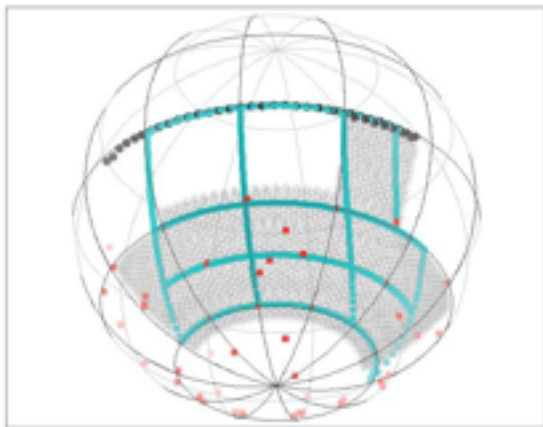
Observations took place in Aug/Sep 2010 and Nov 2010 - Jan 2011.

1

PreCam: a "mini-DECam," camera developed & built at ANL

- Science motivation for pre-survey observations with DECam hardware:
  - 0.01 calibrated stars/image w/o PreCam, ~1000/image with PreCam

  - reach 2% photometry requirement faster, and better chance at 1% goal

  - possible 10% savings (~$1M!) in telescope time

- Test-bed for DECam hardware, software, and observing strategies
- PreCam science run and First Results, ~500 images/night
- From FNAL Director's Review: "Data from PreCAM plays a key role in the calibration." It is "imperative that PreCam...be finished before the end of the 2012-2013 observing campaign."

PreCam Grid overlaid on DES Footprint, with Standard Star Fields

Constant	9.979 ± 2.383
Mean	0.002515 ± 0.007470
Sigma	0.02568 ± 0.00777
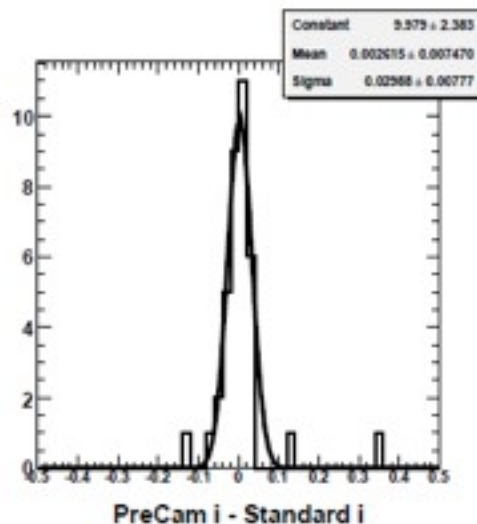
PreCam i - Standard i

i-band comparison to USNO standards on equator, σ=2-3.5%

Kyler Kuehn (ANL) and Jorge Briones (CTIO) during camera installation (Aug 30, 2010).

Tuesday, May 24, 2011

PreCam Timeline

Project Approval, Postdoc Hire: Late 2009
Mechanical Design: starting November 2009
Budget in place, first purchases: Jan 2010

System Assembly: Feb - June 2010
Component Tests: May - June 2010
Integrated System Tests: June - July 2010
PreCam Ships: August 2010 (6 months from assembly start!)
Installation & Commissioning late August -September 2010
PreCam Observations: November 2010 - January 2011
Data Analysis: January 2011 - Present
Less than One Year from Project Start to Data-Taking!

Basic DES Observing Strategy

Observing Strategy

- 100 sec exposures (nominally)

- 2 filters per pointing (typically)
  - *gr* in dark time
  - *izy* in bright time

- Multiple overlapping tilings (layers) to optimize photometric calibrations

- 2 survey tilings/filter/year

- Photometric Requirements (5-year)
  - All-sky internal: 2% rms (Goal: 1% rms)
  - Absolute Color: 0.5% (*g-r*, *r-i*, *i-z*); 1% (*z-y*)
  - Absolute Flux: 0.5% in *i*-band (relative to BD+17 4708)

Survey Area

Credit: J. Annis

Overlap with SDSS Stripe 82 (200 sq deg)

Connector region (800 sq deg)

Main survey region (4000 sq deg)
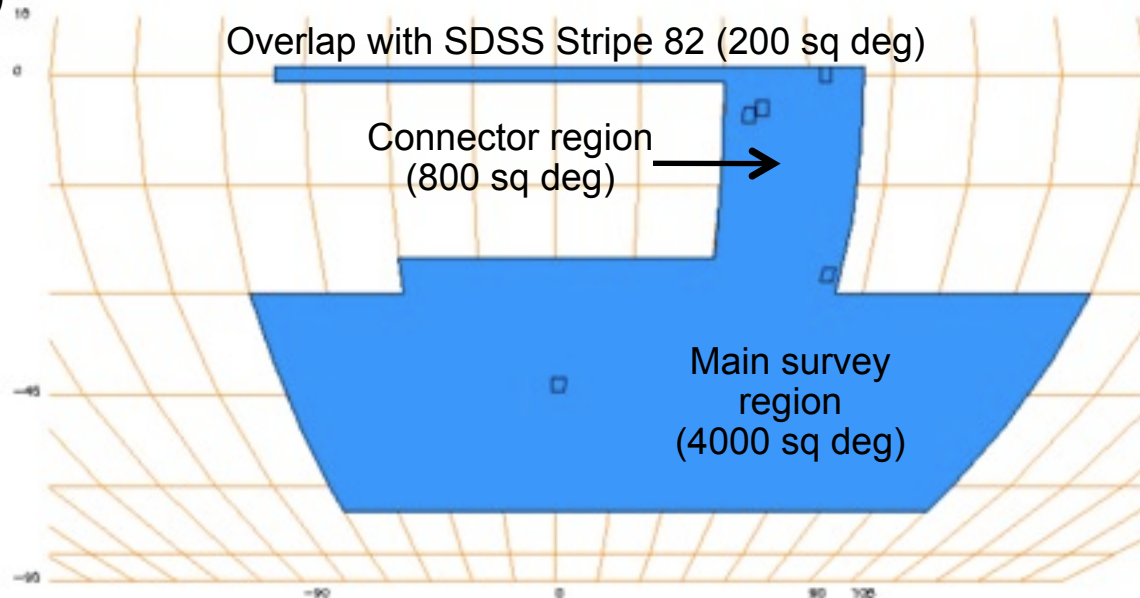
Total Area: 5000 sq deg

DES Calibrations Plan in 6 Points

1. **Instrumental Calibration (Nightly & Periodic):** Create biases, dome flats, linearity curves, cross-talk coefficients, system response maps.

2. **Photometric Monitoring:** Monitor sky with 10μm All-Sky Cloud Camera.

3. **PreCam Survey:** Create a network of calibrated DES *grizy* standard stars for use in nightly calibrations and in DES Global Relative Calibrations.

4. **Nightly and Intermediate Calibrations:** Observe standard star fields with DECam during evening and morning twilight and at least once in the middle of the night; fit photometric equation; apply the results to the data.

5. **Global Relative Calibrations:** Use the extensive overlaps between exposures over multiple tilings to tie together the DES photometry onto an internally consistent system across the entire DES footprint.

6. **Global Absolute Calibrations:** Use DECam observations of spectro-photometric standards in combination with measurements of the full DECam system response map to tie the DES photometry onto an AB magnitude system.
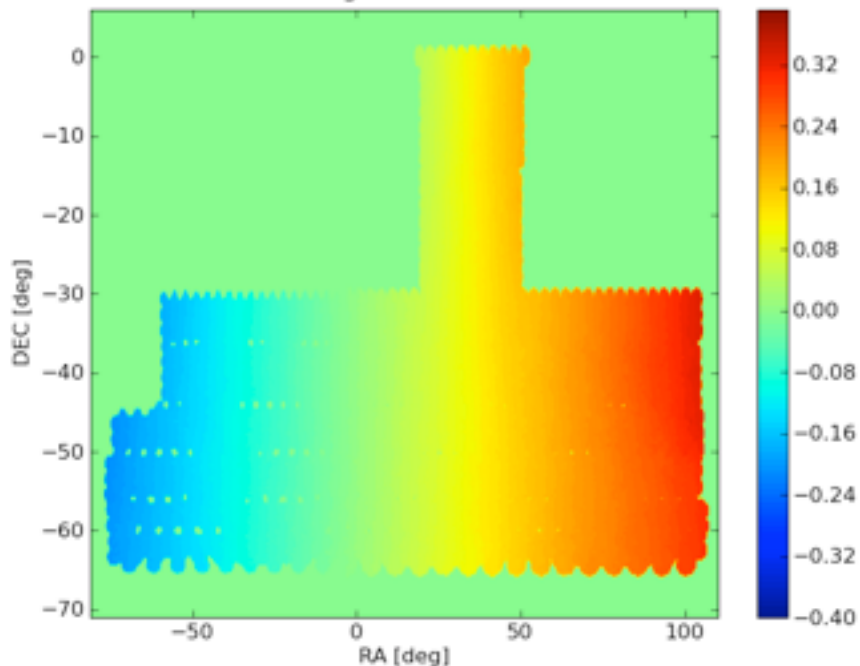
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# Global Relative Calibrations:
The Role of PreCam Data

- A rigid framework onto which to tie the DES photometry
- PreCam helps DES achieve its global relative calibrations requirements sooner (and also helps protect against certain pathological calibration failures).
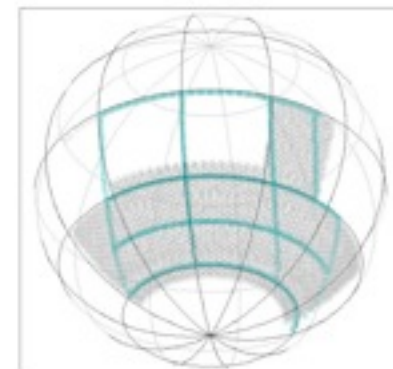
Pessimal DES g band Years 1&2 Alone

Pessimal DES g band Years 1&2 + Median Realistic PreCam Rib&Keel
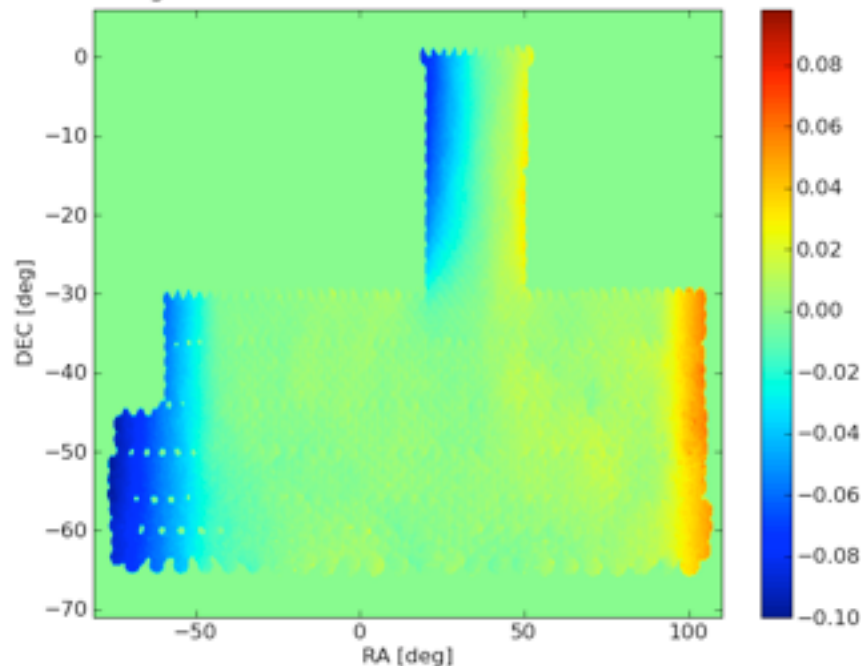
Nightly/Intermediate Calibrations: Standard Stars for DES

Photometric Equation: $m_{inst} - m_{std} = a_n + b_n \times (stdColor - stdColor_0) + kX$

SDSS Stripe 82
- ~10^6 tertiary *ugriz* standards
- r = 14.5-21
- ~4000 per sq deg
- 2.5° x 100° area
- See Ivezic et al. (2007)

PreCam
- DES *grizy*
- 500 sq deg
- ≈200 per sq deg

Southern u'g'r'i'z' Standards
- Sixty 13.5'x13.5' fields
- r = 9-18
- Typically tens per field
- See http://www-star.fnal.gov/Southern_ugriz/
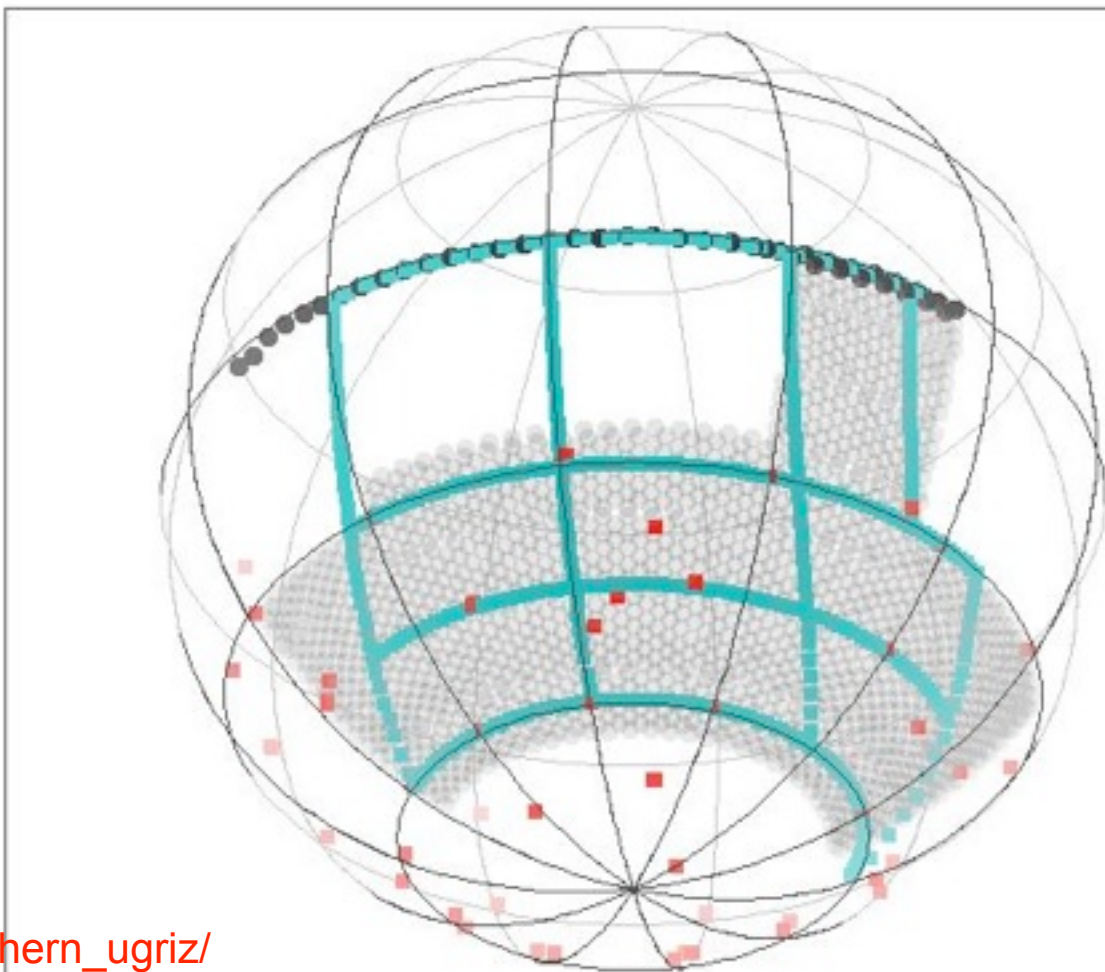
The PreCam Survey:
Characteristics

- 2 DECam 2k x 4k CCDs
  - FOV of 1.6º x 1.6º (2.56 sq deg) at a pixel scale of 1.4 arcsec/pixel
- 112 scheduled nights (which includes includes installation & commissioning)
- Goals: to act as a test-stand of DECam h/w and s/w and to obtain a sparse-but-rigid gridwork of stars in DES *grizy* photometrically calibrated to better than ~1%

Baseline PreCam Survey Point-Source Magnitude Limits (optimized to achieve S/N=50 at DES saturation + 1.5mag)

Band	Exposure time [seconds]	PreCam saturation limit	PreCam mag limit S/N=50	Number of usable stars per sq deg (SGP)
g	36	12.8	17.8	186
r	51	13.2	17.8	265
i	65	13.4	17.7	344
z	162	14.1	17.5	317
y	73	11.6	14.3	150

Tuesday, May 24, 2011

Nov-Jan: The Data

- 64 nights allocated (Nov 16-Jan 20 minus Dec 24-25)
  - 1 night lost to weather
  - 2 nights lost to software meltdown on original DAQ computer
  - 2 nights lost to shutter breaking
  - 4 nights devoted to engineering due to shutter-sticking
  - 1 night lost due to venting dewar to ambient atmospheric pressure
  - 1 night lost due to problems with installing new 12-channel DAQ card
  - 2 nights devoted to end-of-run engineering tests

- 51 nights on sky (c. 80% of the 64 nights allocated)

- ~24,000 images

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i-band coverage in
Nov-Jan data.

~5 tilings in g,r,i
in this partial grid

Western fields
not visible at
that time.

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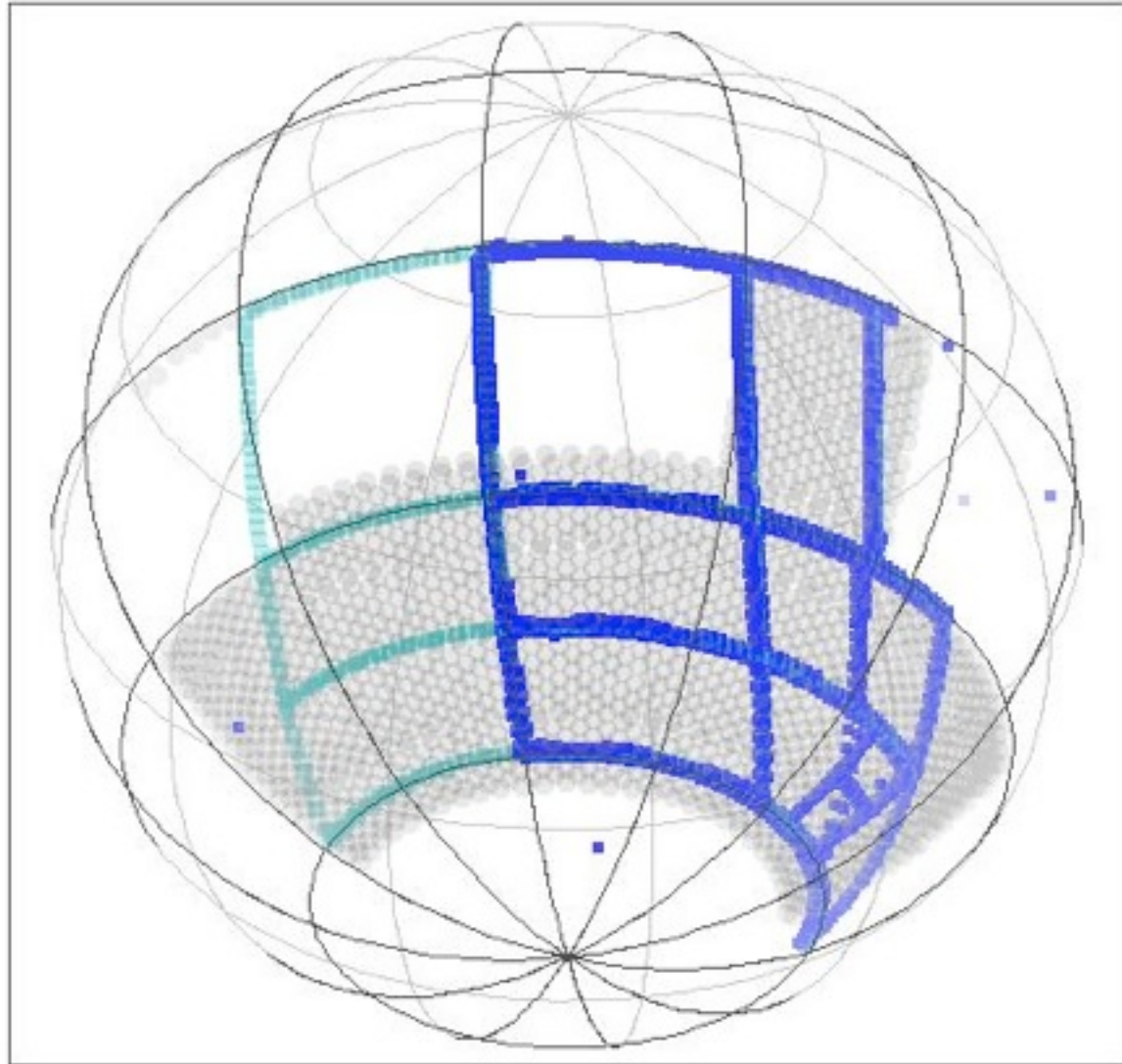
A Processed *i*-band PreCam Image from Jan 13

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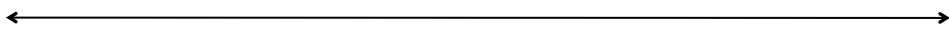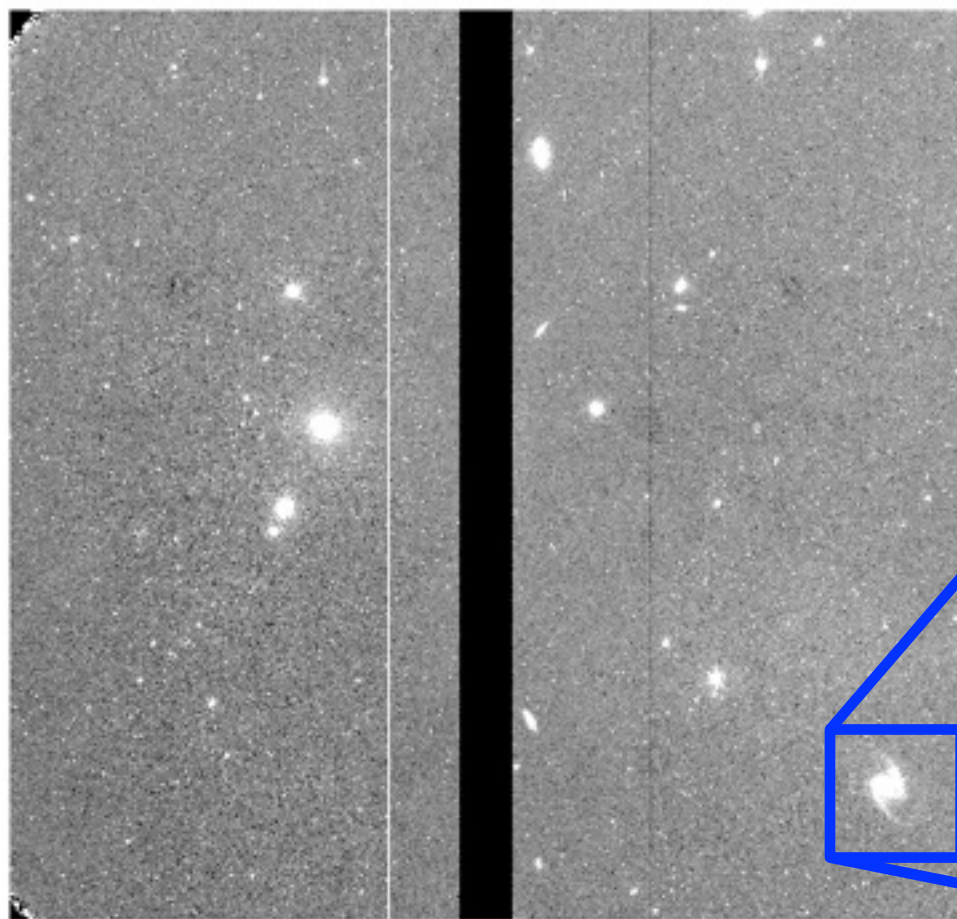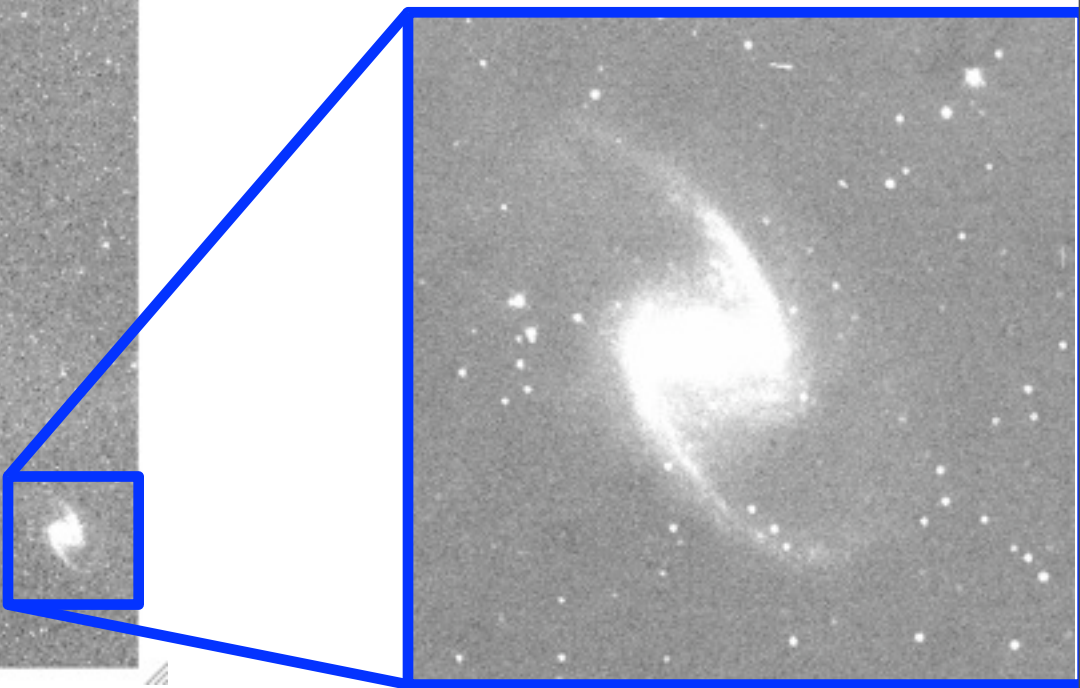
1.6 deg
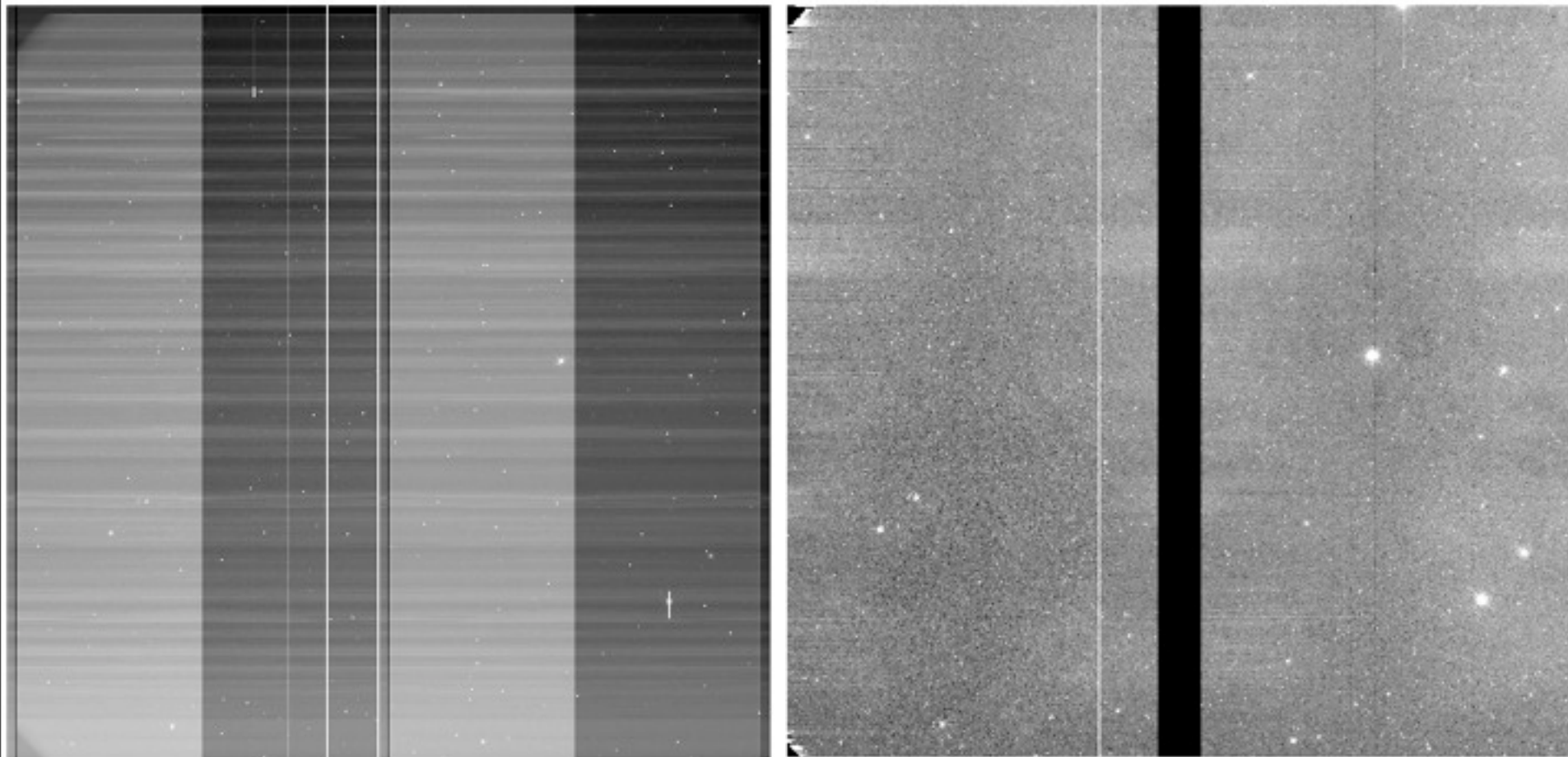
After corrections, horizontal banding & streaking affect only about 6% of images.

**Asahi DECam filters used for PreCam (4"), first test of filter transmission and CCD QE compared to SDSS.**

total throughput

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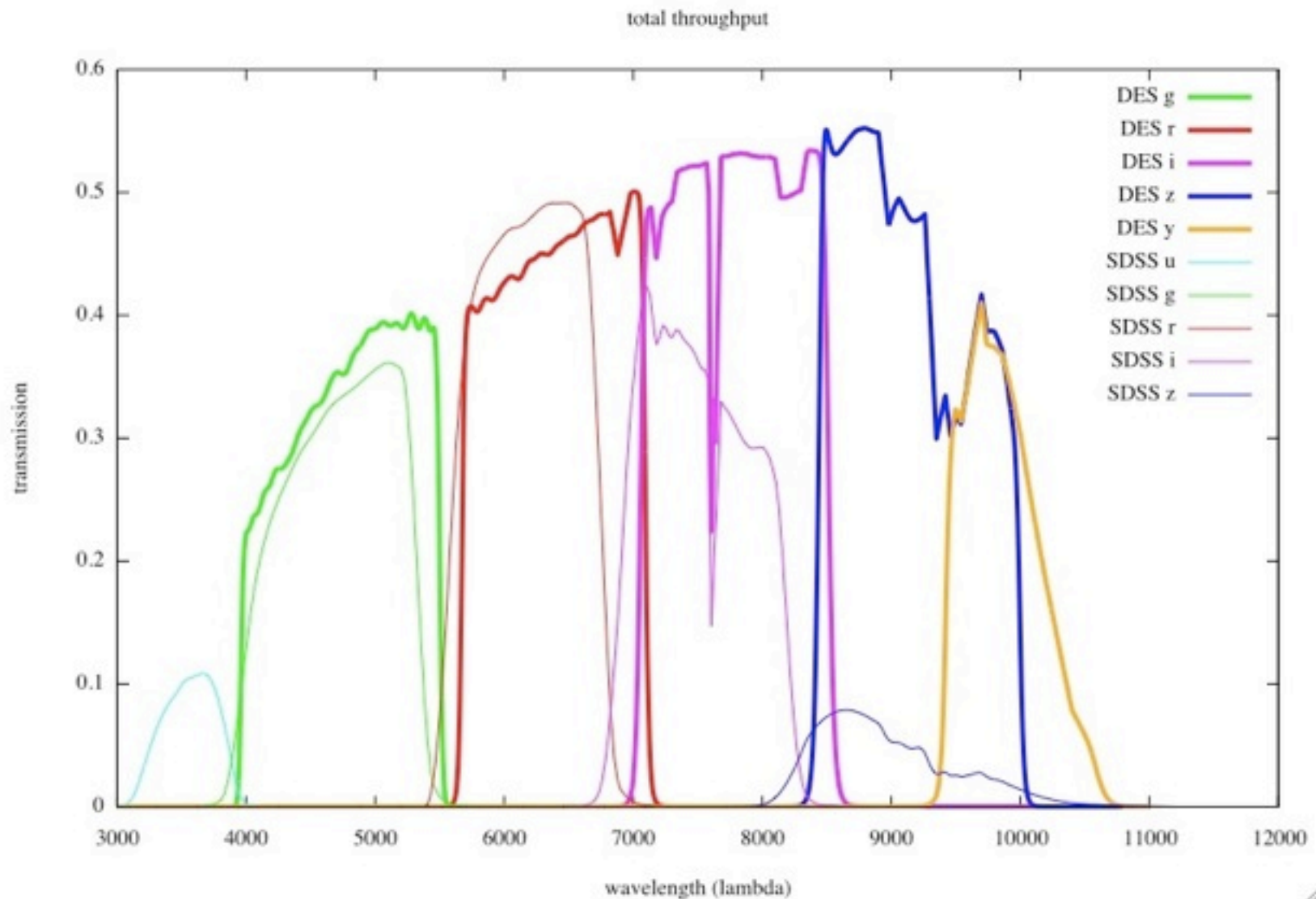
Asahi DECam filters used for PreCam, first test of filter transmission and CCD QE compared to SDSS.

Huan Lin (FNAL) analysis.

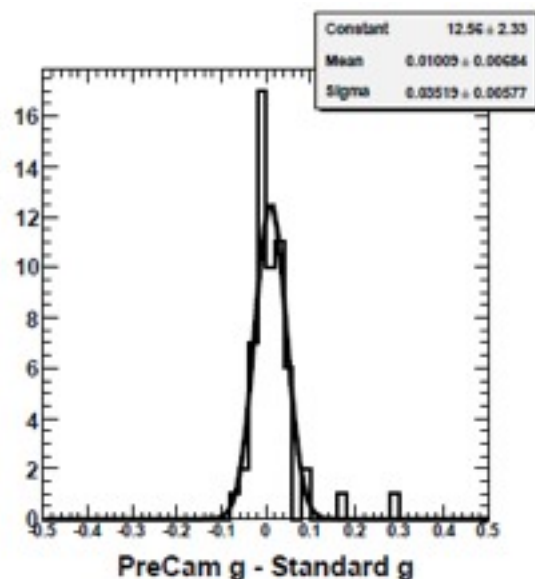Black points are star spectra convoluted with expected PreCam and SDSS filters.

Red points are measured PreCam data compared to SDSS. Very good overlap with black points.

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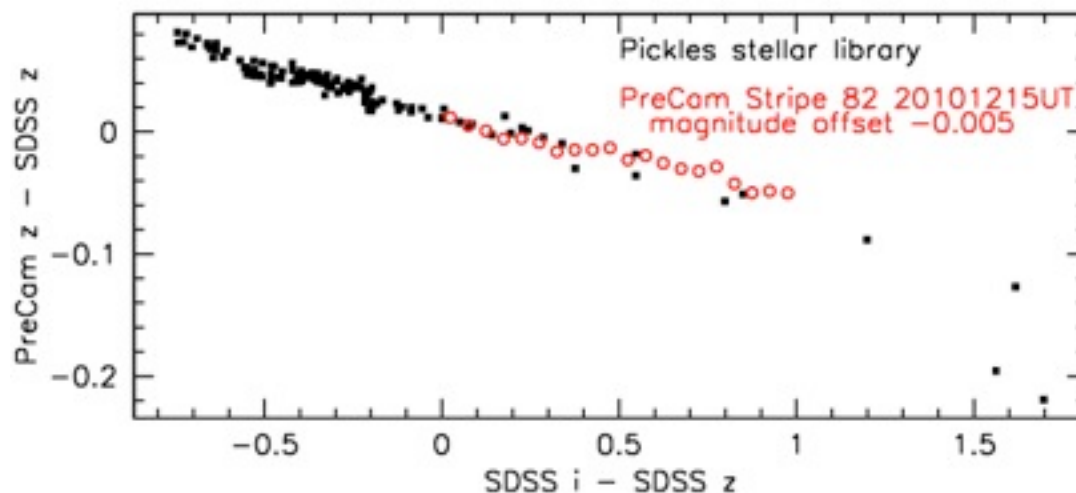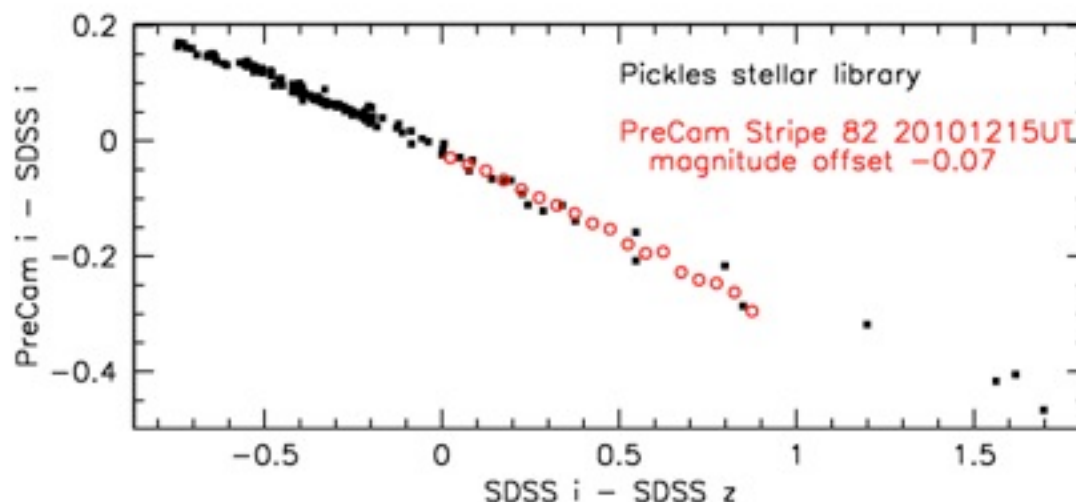
PreCam compared to Southern Standards, mostly mag<14.
No corrections for color terms, vignetting, multiple tilings...

2-3.5% Sigma

PreCam compared to SDSS Standards. Mag<16
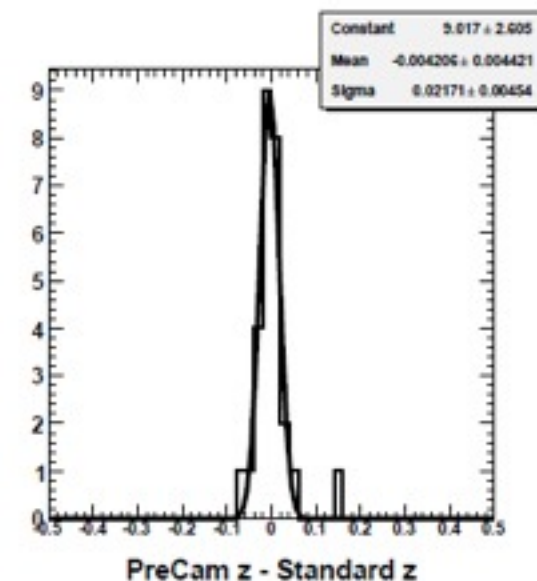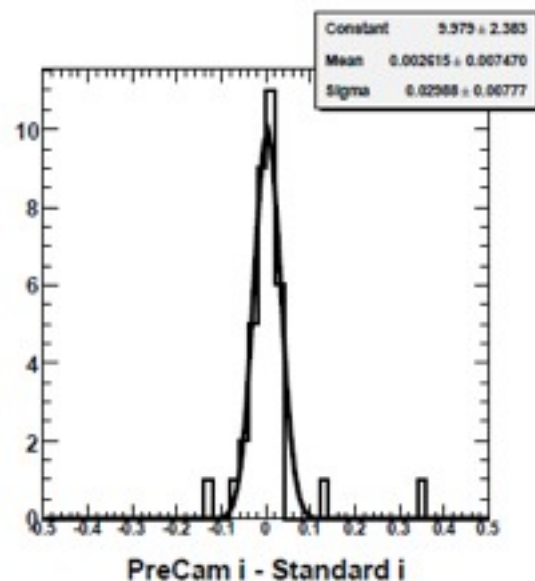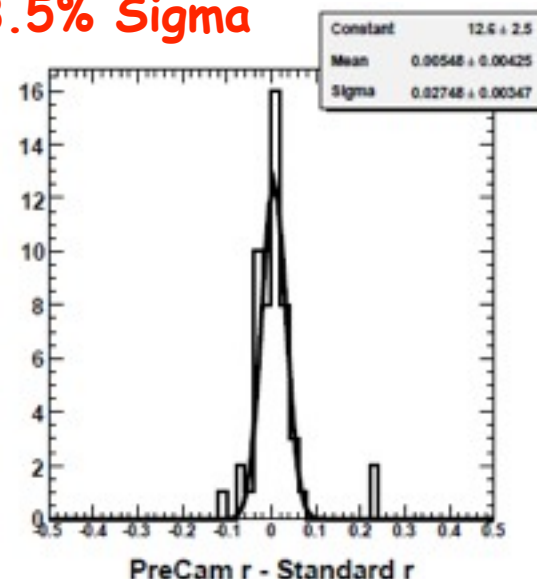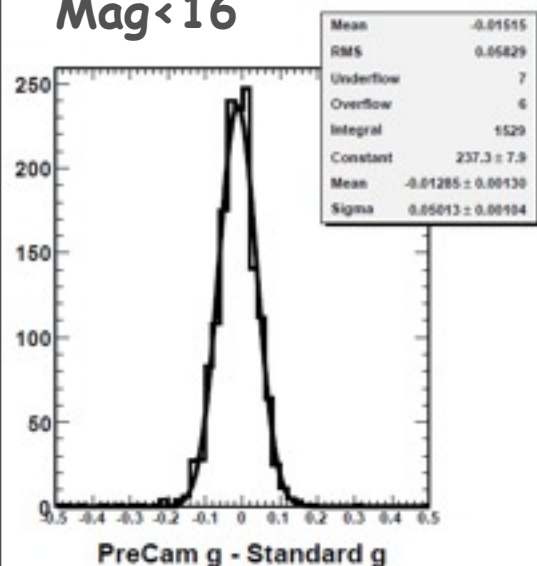
5% Sigma (4.8% with Illumination Correction)

Accomplishments/Lessons Learned Relevant to DES Commissioning

1. **Quick Reduce Commissioning & Experience and Dramatic Improvement in the DES-Brazil Portal**
   - First use of QR during live observing at CTIO

2. **ObsTac Commissioning & Experience**
   - Substantially increased efficiency
   - Basic design showed its flexibility
   - Survey Strategy: Full Moon crosses Stripe 82 (affects survey strategy for *izy*)

3. **DECam Control System (CompactRIO) Experience**
   - 24K shutter exposures with no failures, plus Temp/Vacuum monitoring over 7 months

4. **"Live-fire" Experience with SISPI and Related Observing Software**
   - A special PreCam branch of SISPI

5. **Observing run staffing and training**
   - 16-hour shifts combined with runs longer than 7 nights can be fatiguing, especially when hardware or software problems arise

Plans

1. Determine final detailed plan for official processing.

2. Finish processing data.

3. Analyze data.

4. Determine how much more observing time would be needed to achieve the original PreCam goals (esp. with regards to global relative calibrations of DES), and the consequences of de-scoping if that proves necessary.

5. It is likely that PreCam would need another full season – or two half seasons, since Aug/Sept 2011 might not be available? – to fully achieve its original goals.
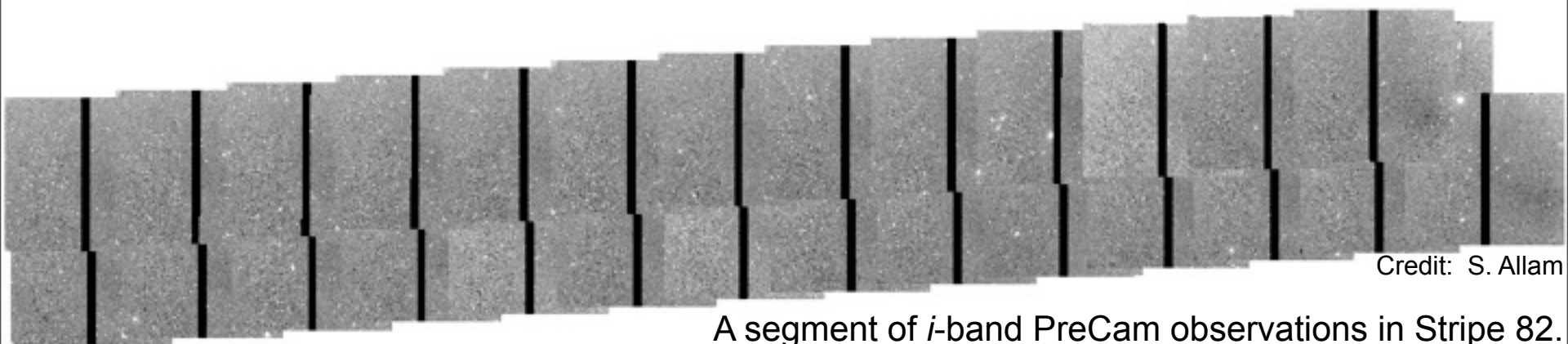
Credit: S. Allam

A segment of *i*-band PreCam observations in Stripe 82.

Extra Slides

Tuesday, May 24, 2011

PreCam on the Curtis-Schmidt

Photo Credits: R. Ogando

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DES Photometric Calibrations Flow Diagram (v4.1)
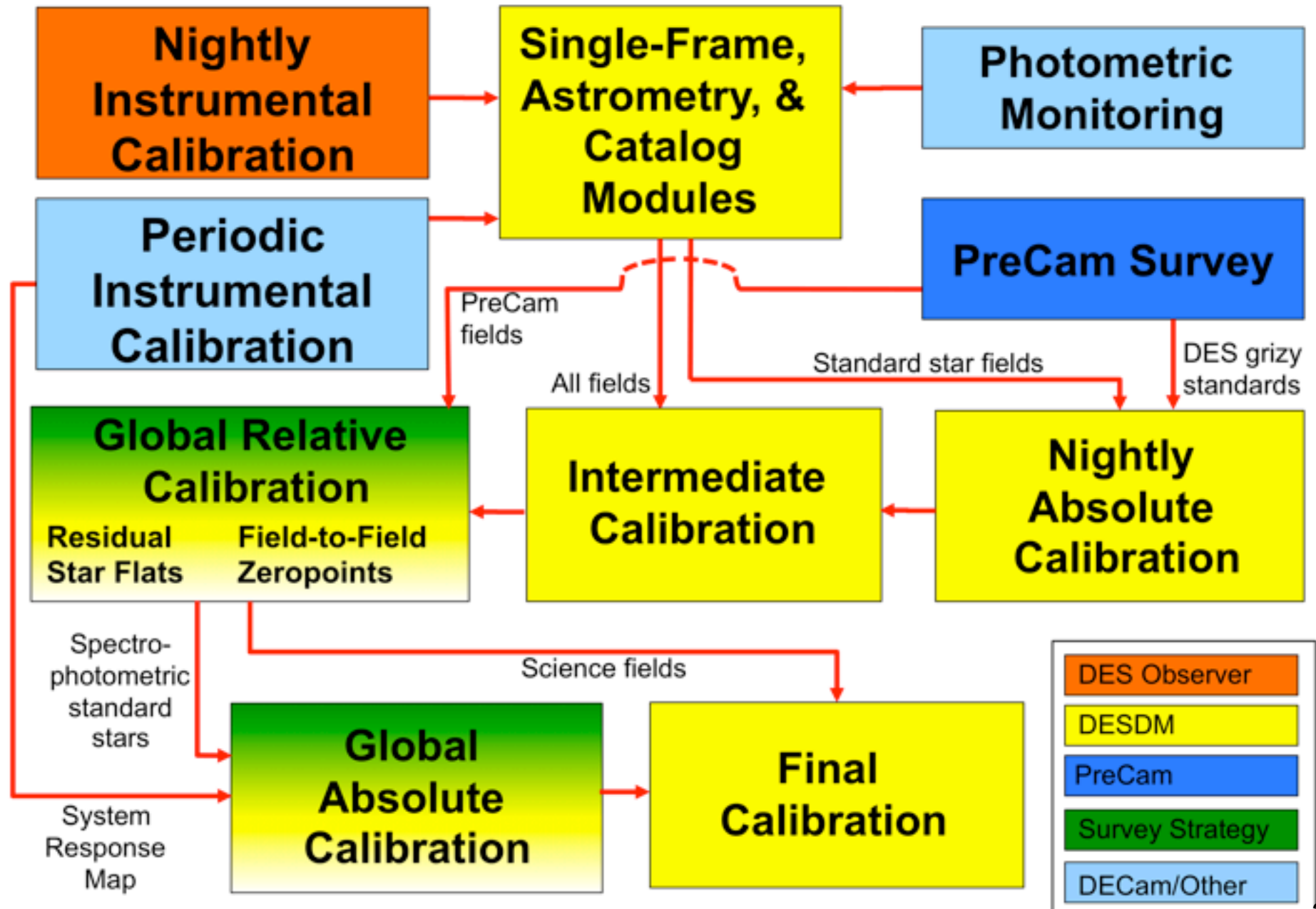
Global Relative Calibrations:
The Need and The Strategy

We want to remove field-to-field zeropoint offsets to achieve a uniformly "flat" all-sky relative calibration of the full DES survey, but…

DES will not always observe under truly photometric conditions…

…and, even under photometric conditions, zeropoints can vary by 1-2% rms field-to-field.
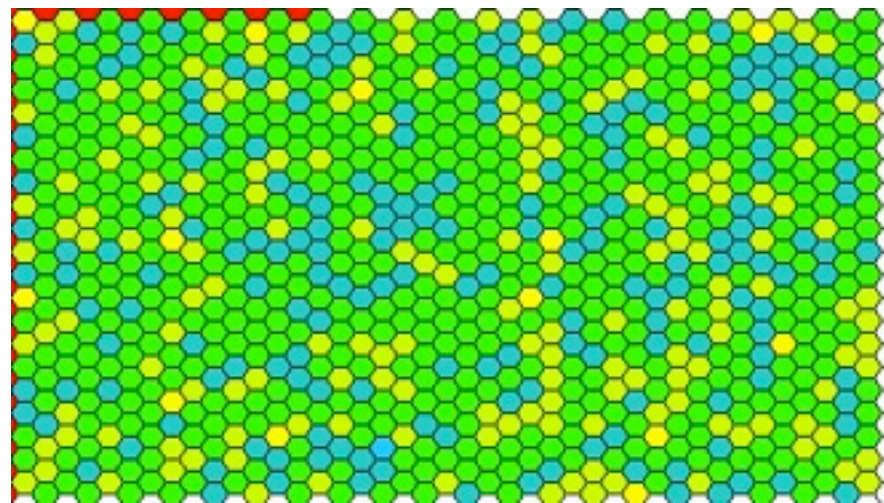
scaling bar is –0.20 mags to +0.20 mags

1 tiling	2 tilings	3 tilings
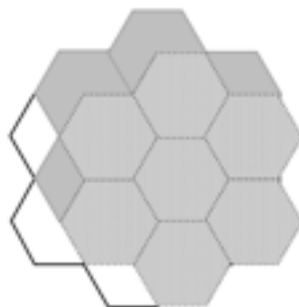
The solution: multiple tilings of the survey area, with large offsets between tilings.

We cover the sky twice per year per filter. It takes ~ 1700 hexes to tile the whole survey area.

Jim Annis
DES Collaboration Meeting,
May 5-7, 2005

Tuesday, May 24, 2011

August-September Successes

1. Safely shipped PreCam, PreCam computers, PreCam CCDs, and auxiliary equipment to CTIO and mounted on the Curtis-Schmidt (C-S).

2. Hardware upgrades to C-S, including new TAMU dome flat system.

3. Quick Reduce and data transfer installed on PreCam computers

4. Preliminary observing scripts written.

5. Realigned optics with powerful new quantitative technique.

6. Identified problems to be fixed.

7. **PreCam on sky!**

8. **Built successful PreCam team!**

Credit: S. Allam
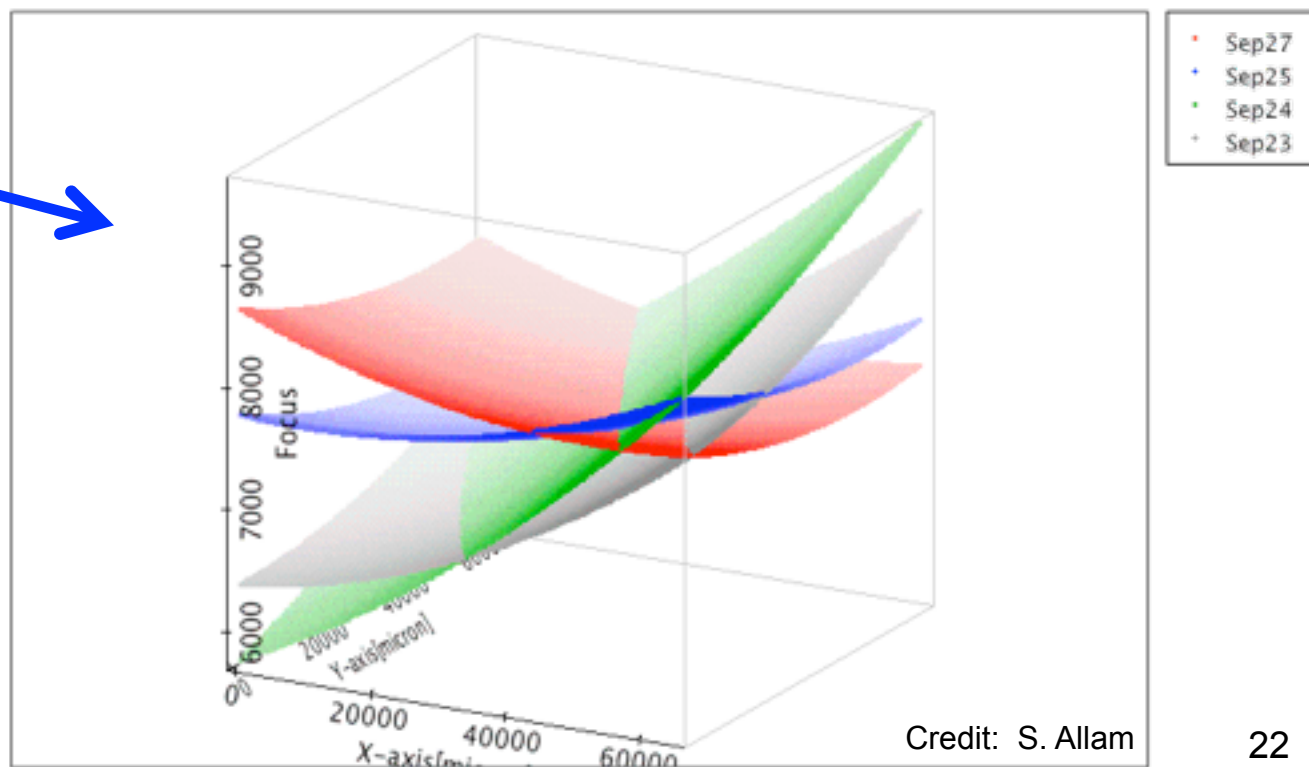
Actual PreCam Coverage as of Jan 20

Tuesday, May 24, 2011
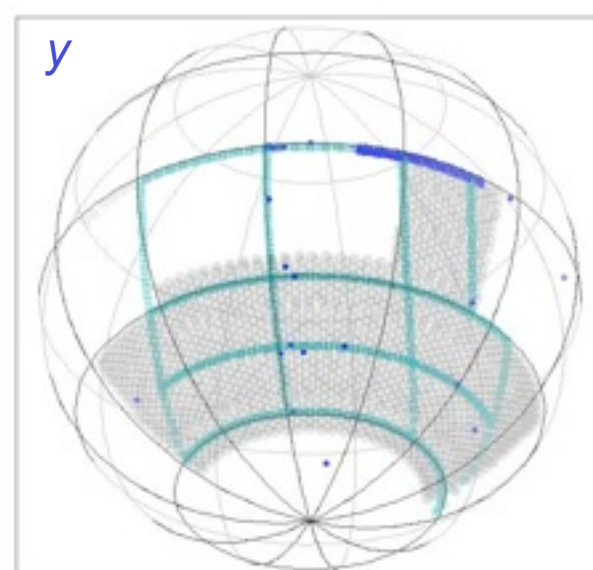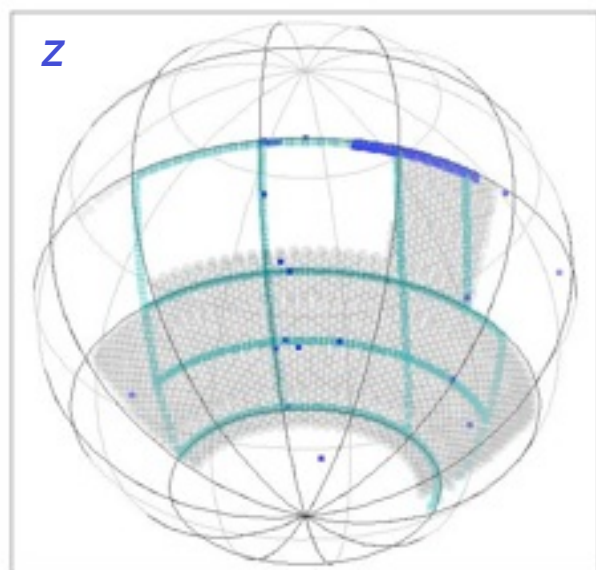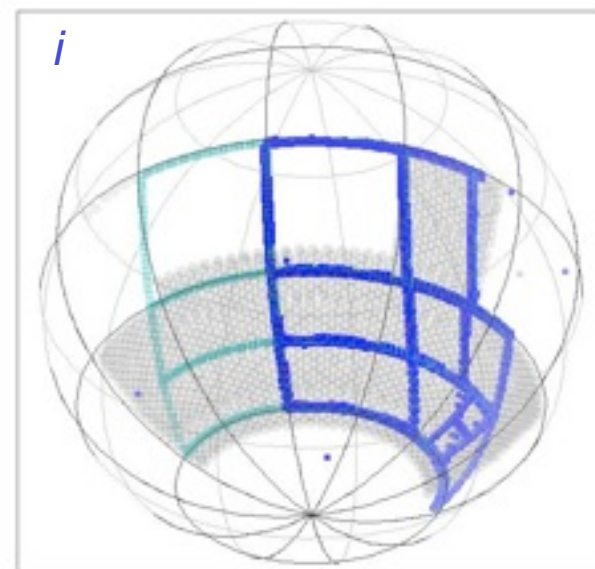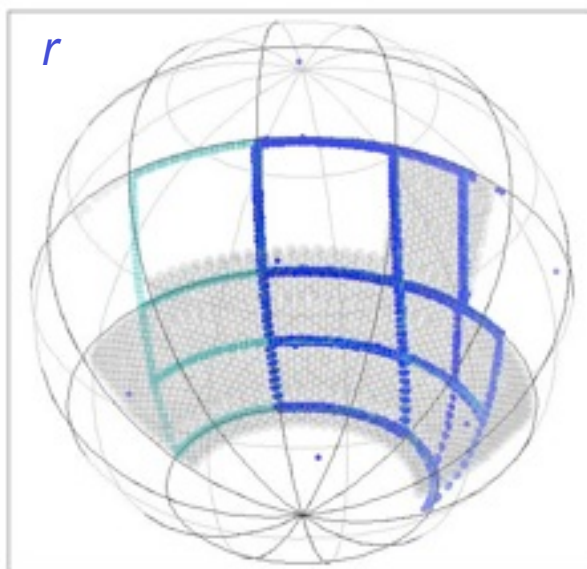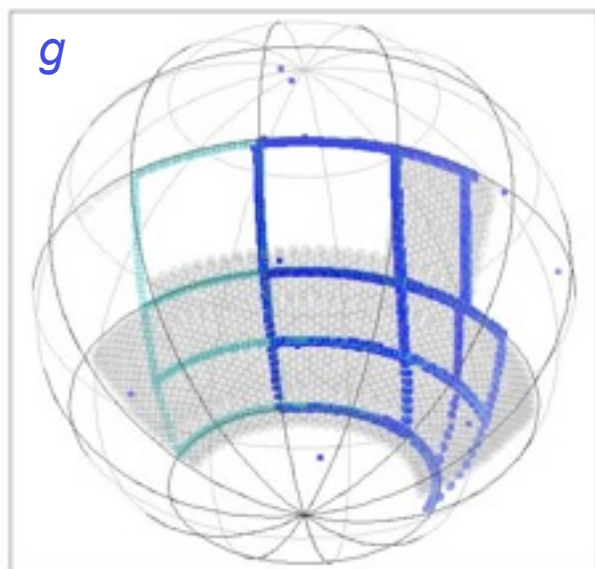
Data Processing

- **DES-Brazil Effort**
  - The official data processing.
  - Uses a PreCam-specific version of the Quick Reduce Pipeline.
    - Quick Reduce in turn uses the DESDM code.

- **FNAL/ANL Effort**
  - R&D effort using custom scripts in order to understand the data and obtain some quick results.
  - Provides feedback to the official data processing.

- **"Golden Nights"**
  - A set of 5 nights with robust FITS headers, no known problems, and target observations in SDSS Stripe 82.
  - Used by both data processing efforts for rapid testing and algorithm development.
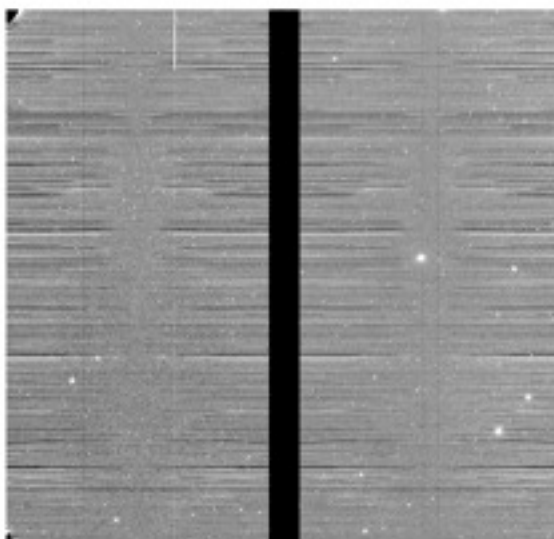
Tuesday, May 24, 2011

Results:
Horizontal Banding & Streaking
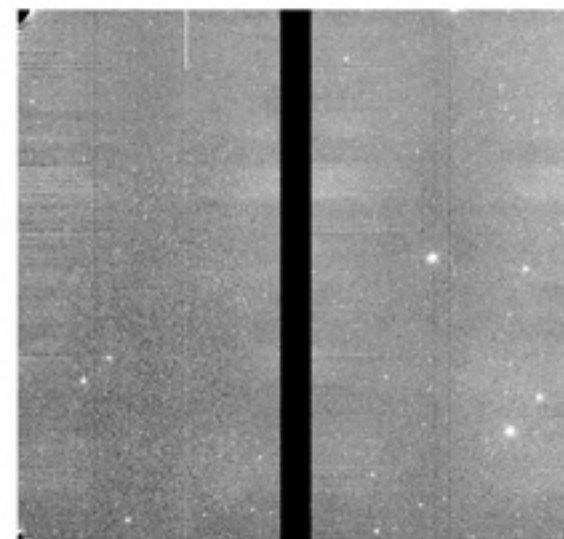
A Pretty Bad Case of Banding and Streaking

Original Image
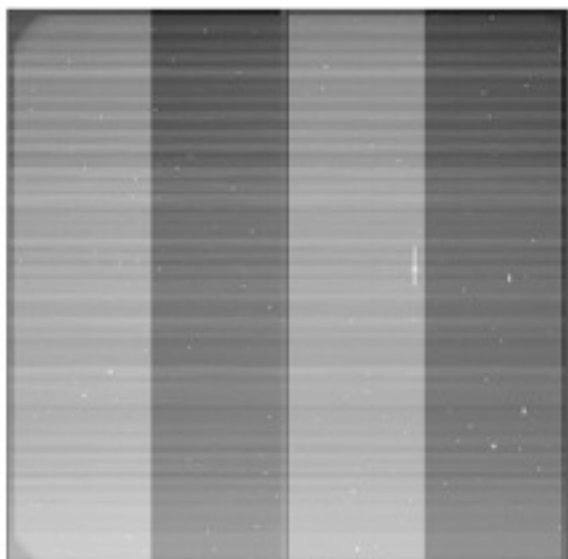
After row-by-row overscan subtraction
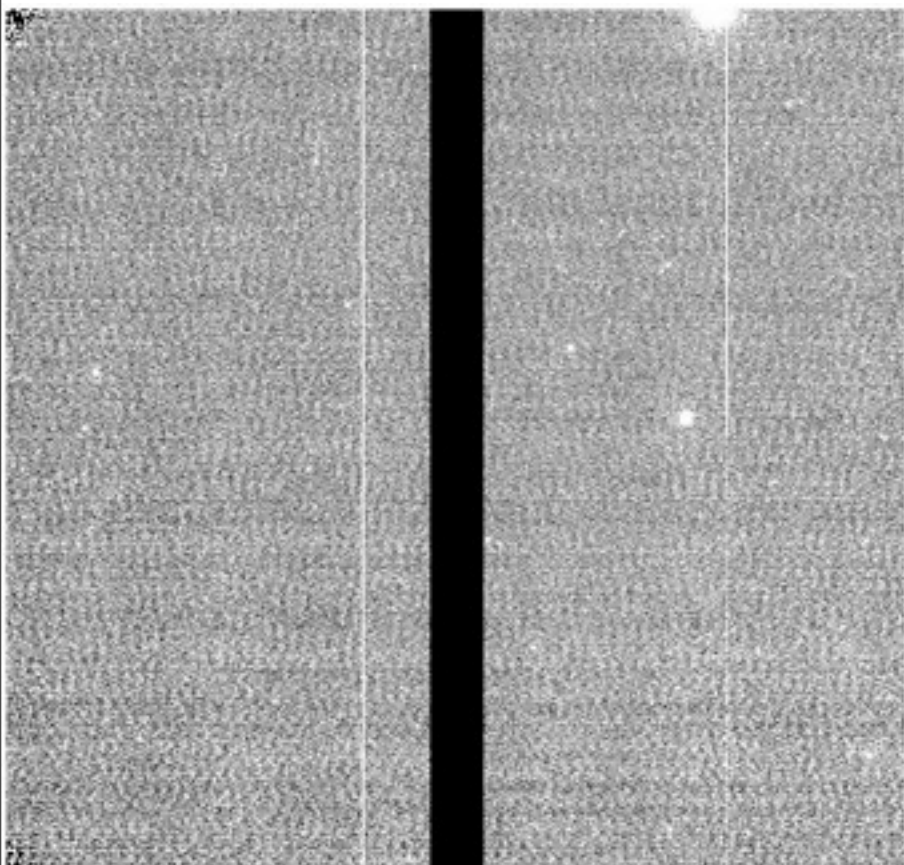
After horizontal streaking correction

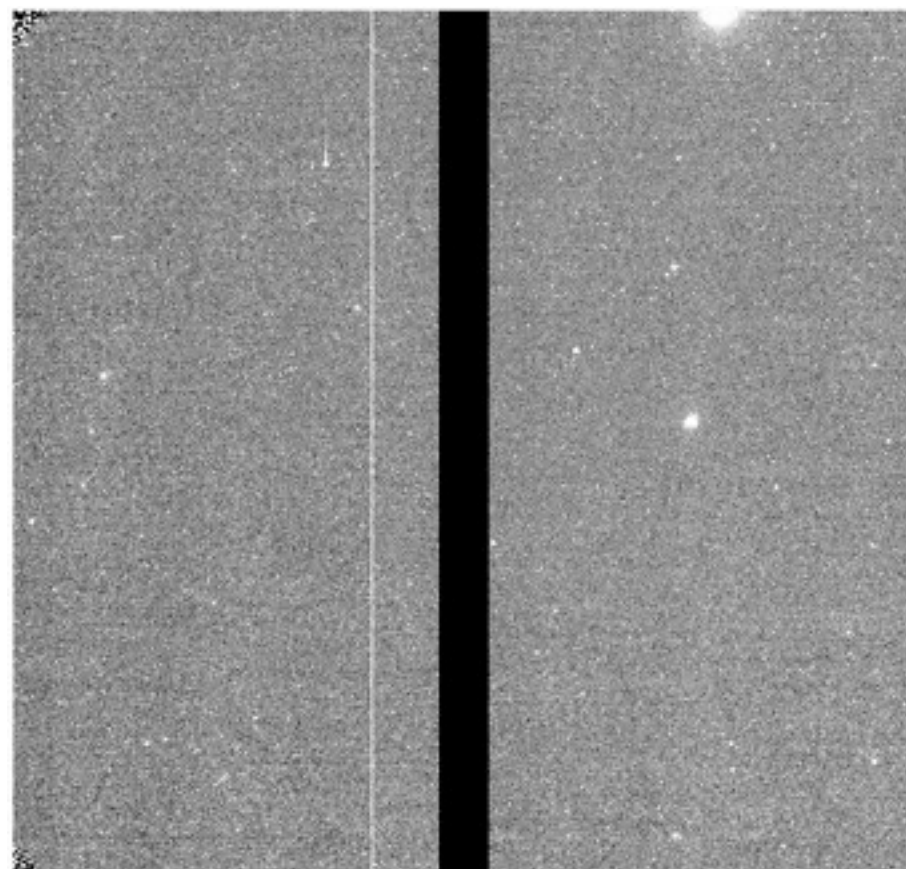**After corrections, horizontal banding & streaking affect only about 6% of images.**
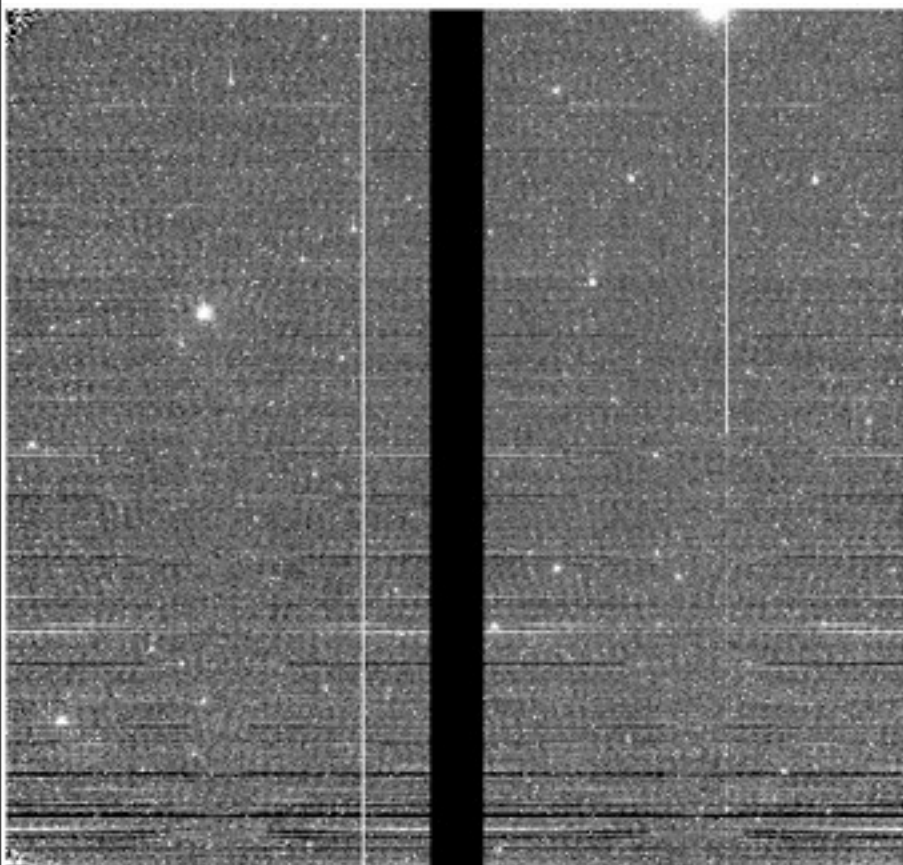
Credit: S. Allam & T. Biesiadzinski

25

Tuesday, May 24, 2011

More Examples: Before and After Horizontal Streaking Correction

Before

After

Credit: S. Allam

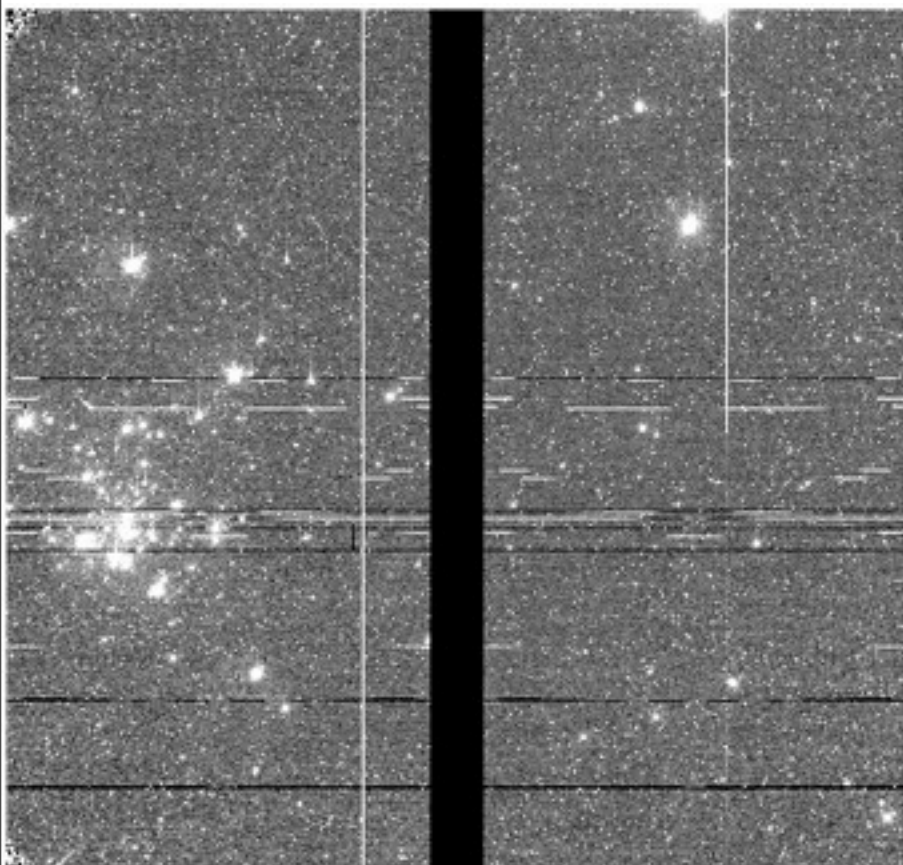# More Examples: Before and After Horizontal Streaking Correction

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Before

After

Credit: S. Allam

Tuesday, May 24, 2011

More Examples: Before and After Horizontal Streaking Correction

Before

After

Credit: S. Allam
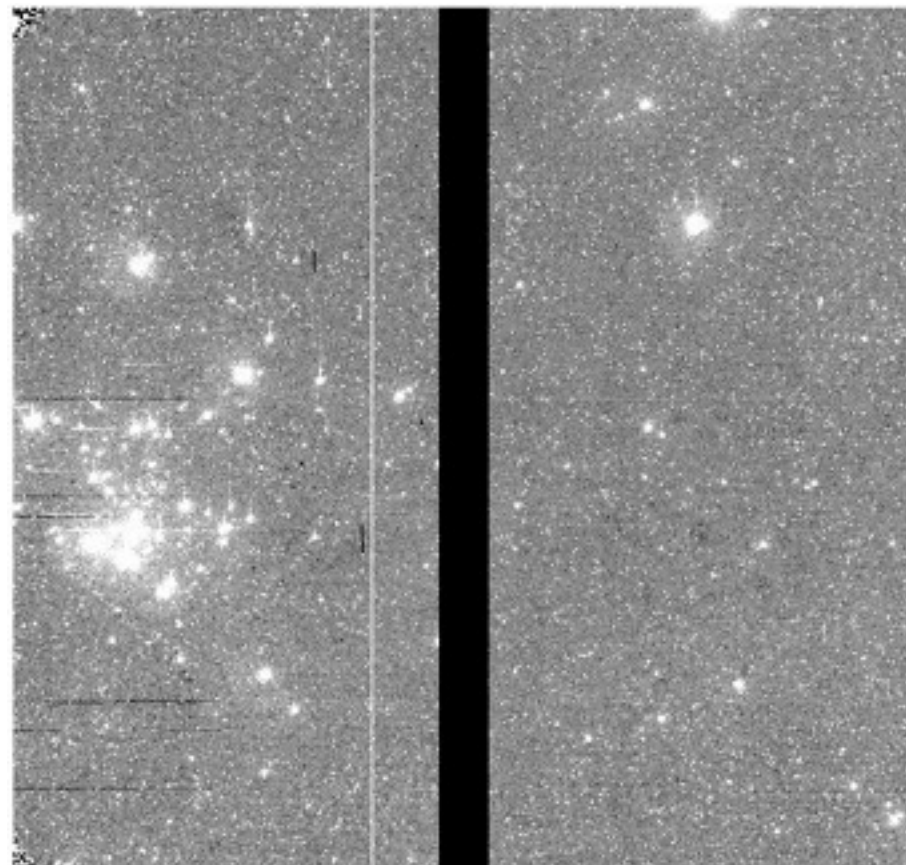
Tuesday, May 24, 2011
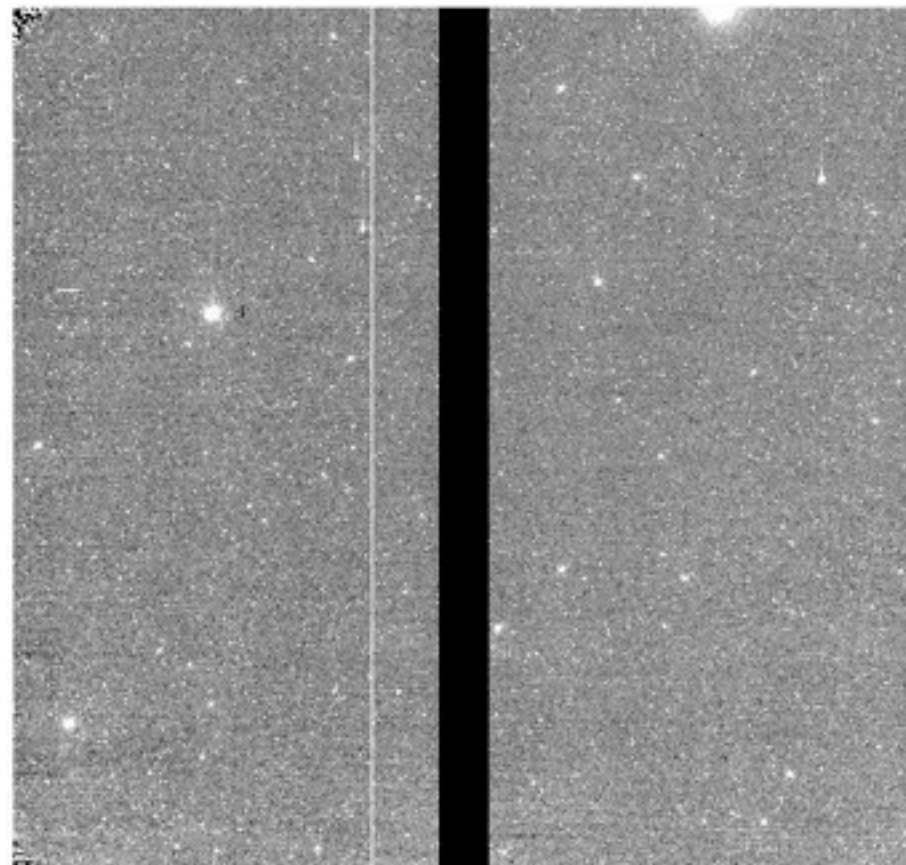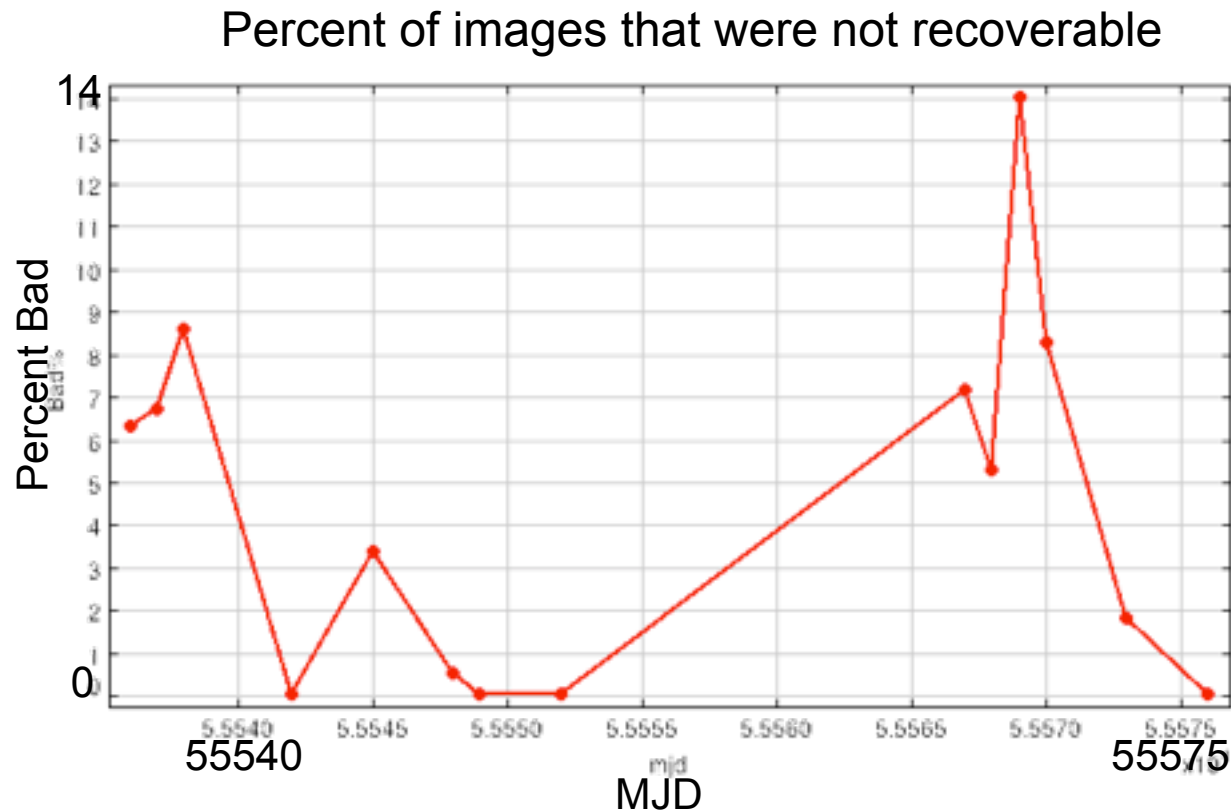
Results:
Horizontal Banding & Streaking

- Horizontal banding & streaking affect ≈40% of the raw PreCam standard star field and science target images.

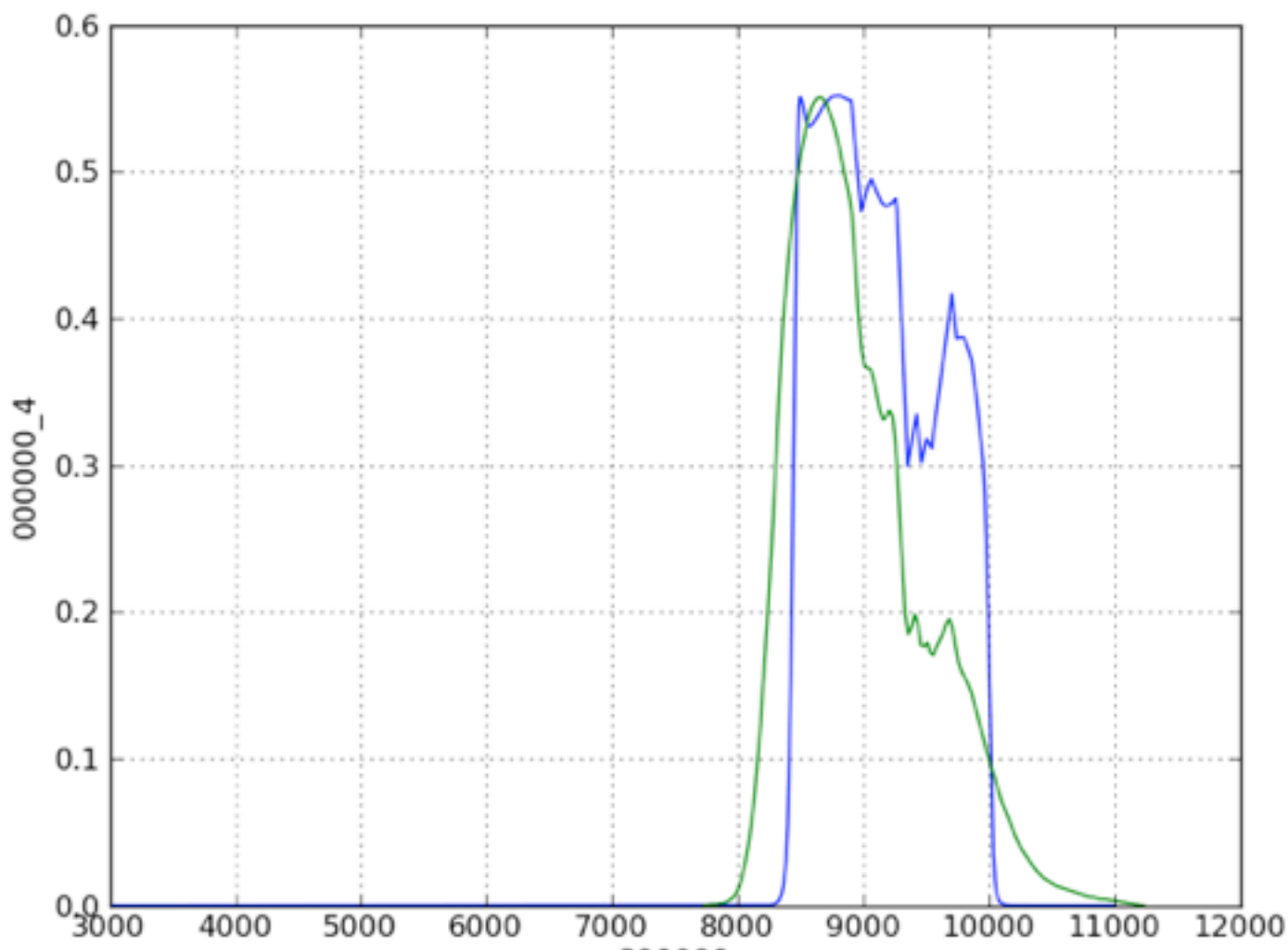- After correcting, horizontal banding & streaking affect only about 6% of the processed images.
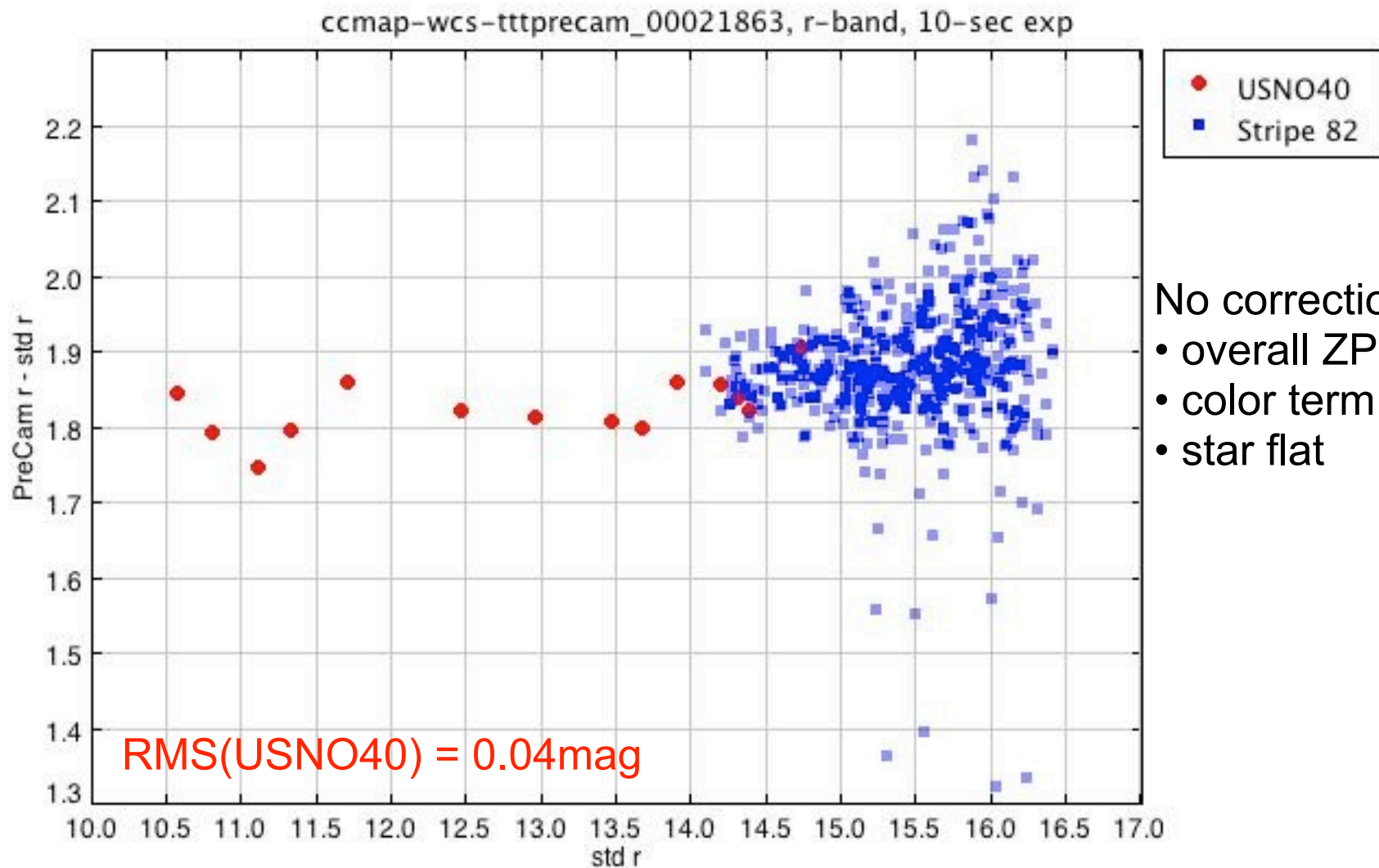
Percent of images that were not recoverable

Credit: S. Allam

DES Z Filter vs. SDSS Z Filter (x 7)

Results:
Initial Photometry for a Single Image

ccmap-wcs-tttprecam_00021863, r-band, 10-sec exp

No corrections for:
- overall ZP
- color term
- star flat

RMS(USNO40) = 0.04mag

Tuesday, May 24, 2011

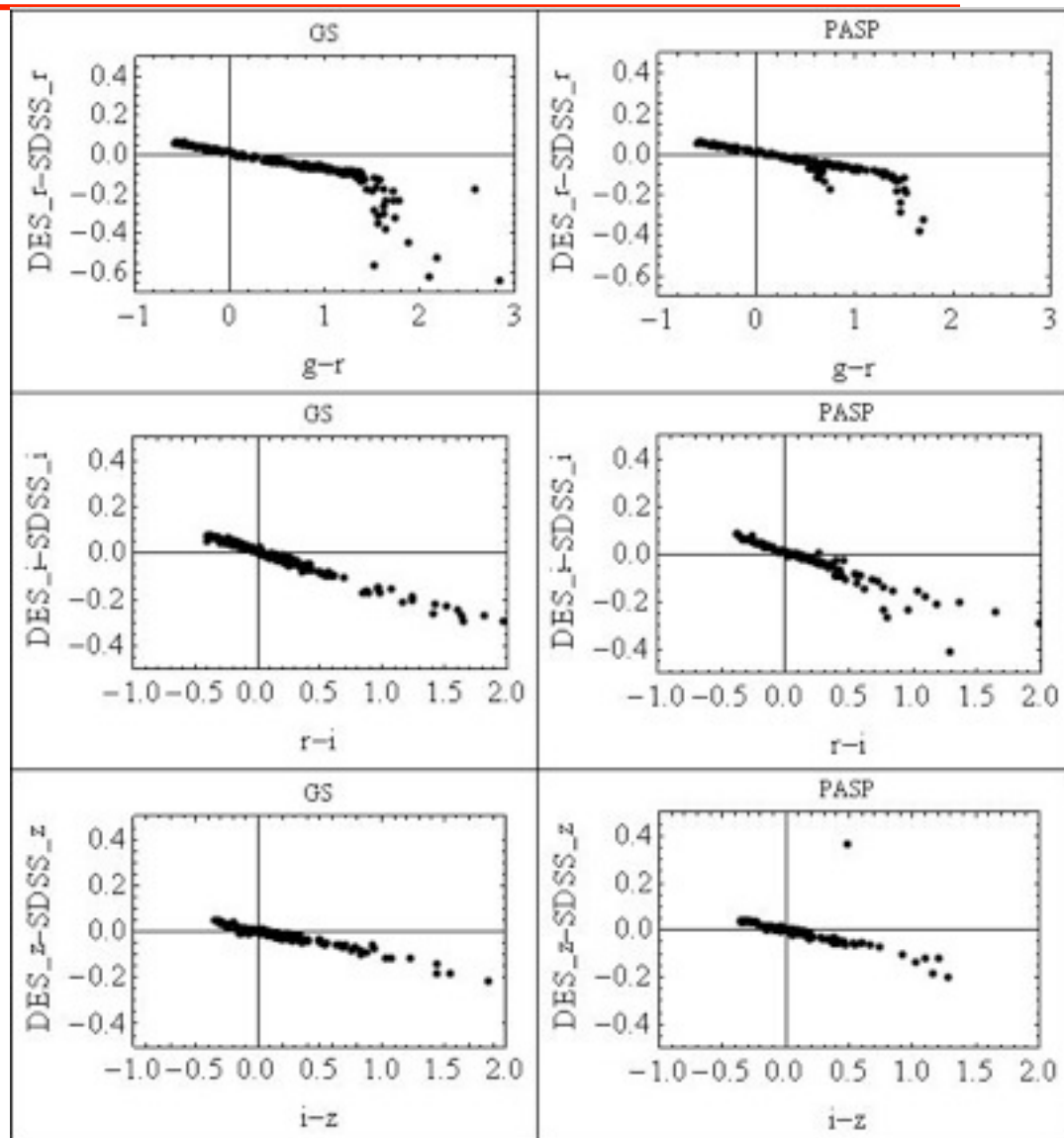**Expected vignetting due to small secondary mirror observed, future correction.**

Tuesday, May 24, 2011
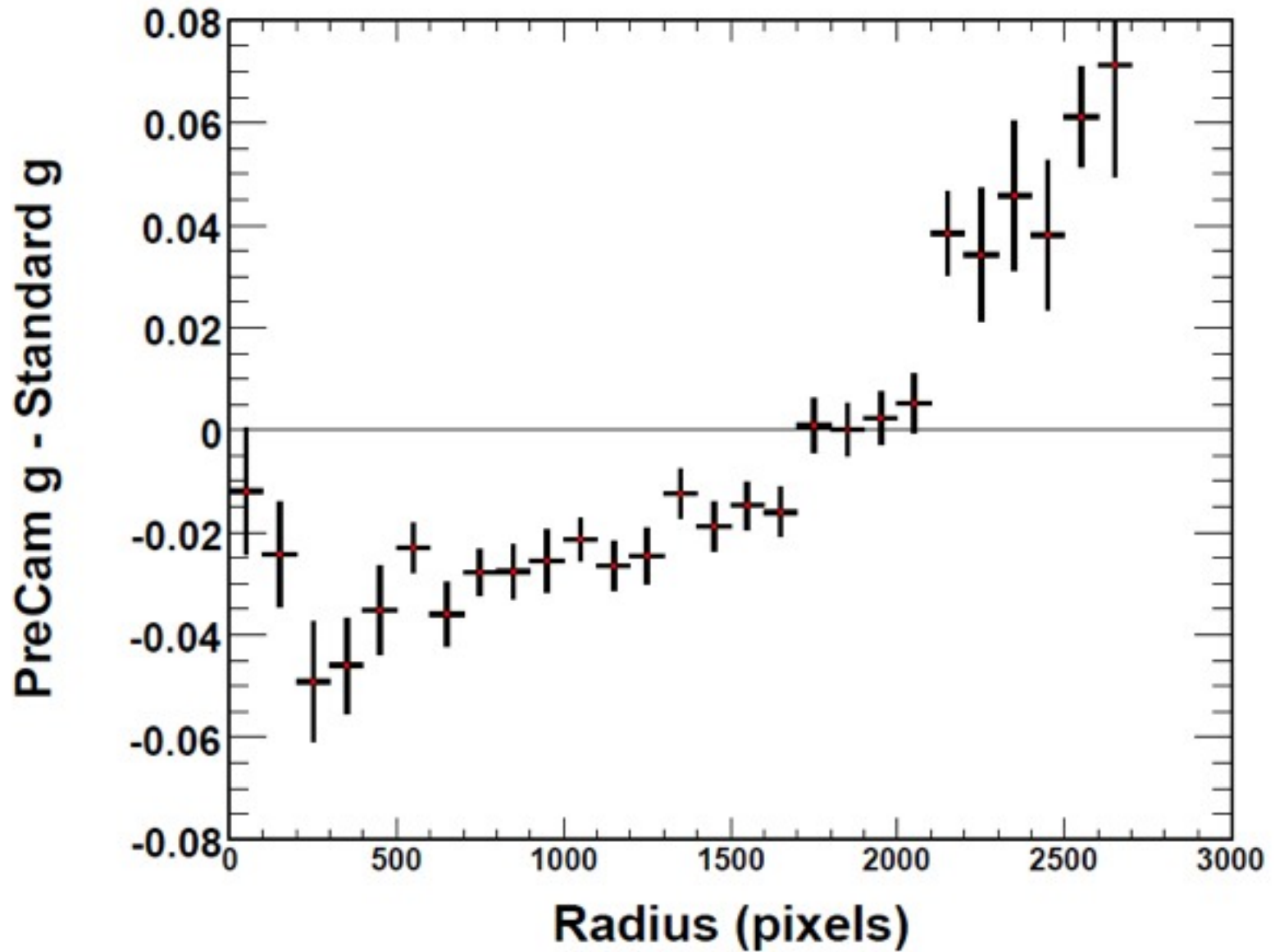
Results:
DES-SDSS Color Terms

- Synthetic color terms.

- Transmission curves from the PreCam set of 100mm x 100mm DES *grizy* filters.

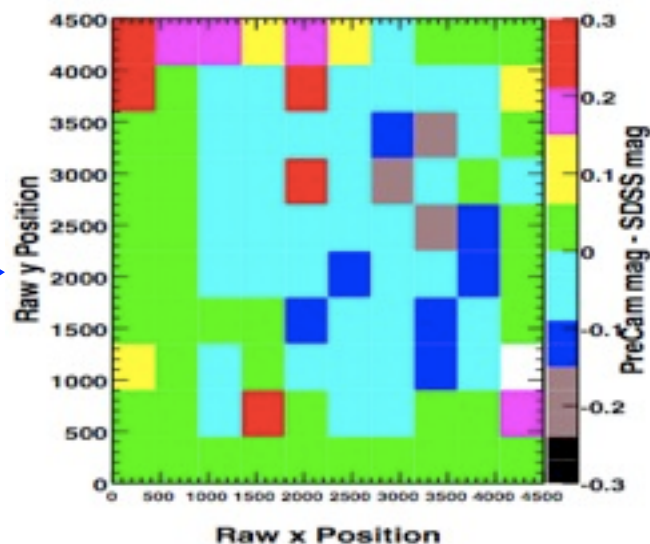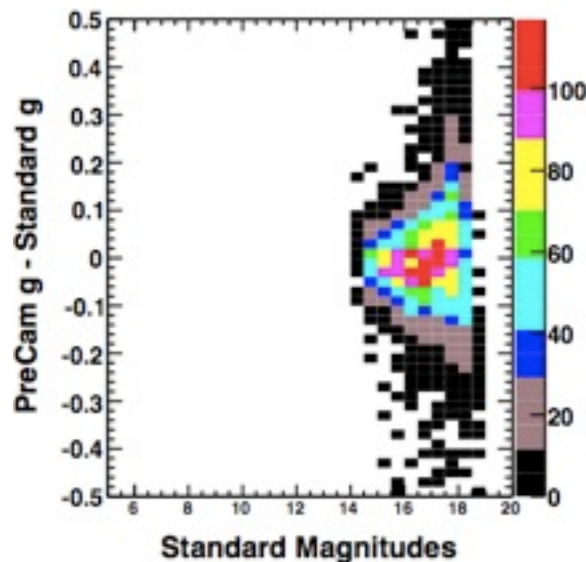- Stellar libraries from Gunn-Stryker (GS) and Pickles (PASP).

Credit: V. Bragança

Results:
Photometry in SDSS Stripe 82

- Night of 7 Jan 2011 UT.

- 11 *g*-band images within SDSS Stripe 82.

- Corrections for overall ZPs and for airmass (using site-average first-order extinction coefficients)

- RMS = 9% (mag = 14 - 19).

- No correction for color terms or for variations across focal plane.
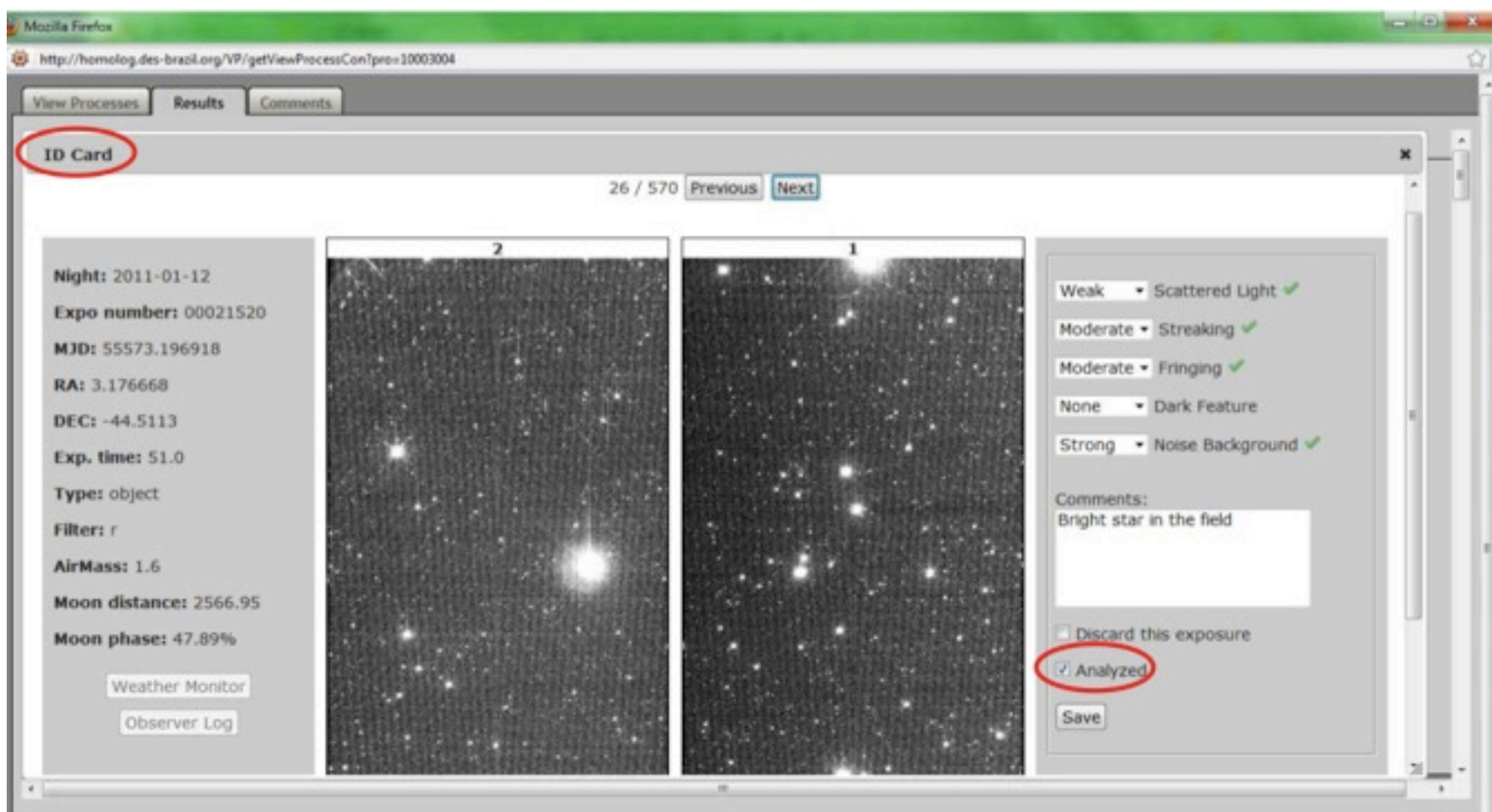

Credit: S. Kuhlmann, H. Spinka

34

Accomplishments/Lessons Learned Relevant to DES Commissioning

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1. Quick Reduce & DES Portal were tested and substantially improved.

Credit: M. Maia

Accomplishments/Lessons Learned Relevant to DES Commissioning

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Accomplishments/Lessons Learned Relevant to DES Commissioning

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2. ObsTac substantially increased observing efficiency, and its basic design demonstrated its flexibility…

Credit: E. Neilsen

DARK ENERGY SURVEY

2. ObsTac substantially increased observing efficiency, and its basic design demonstrated its flexibility…

Observation Totals by Night

MJD	Start	End	Precam Strut	Precam Upright	Precam Standards	DES Survey	DES Supernova	g	r	i	z	y	1	2	3	4	5	6	7	8	9	10
55525	2010-11-25 02:15:22Z	2010-11-25 05:30:55Z	85	0	20	0	0	2	2	27	27	27	85	0	0	0	0	0	0	0	0	0
55526	2010-11-26 00:42:06Z	2010-11-26 06:59:10Z	83	0	81	0	0	28	28	27	0	0	83	0	0	0	0	0	0	0	0	0
55527	2010-11-27 06:00:00Z	2010-11-27 07:34:23Z	43	0	30	0	0	0	0	43	0	0	43	0	0	0	0	0	0	0	0	0
55528	2010-11-28 02:20:00Z	2010-11-28 06:26:46Z	0	124	63	0	0	23	24	77	0	0	124	0	0	0	0	0	0	0	0	0
55529	2010-11-29 00:45:00Z	2010-11-29 07:14:12Z	0	204	100	0	0	49	47	108	0	0	0	123	0	0	0	0	0	0	0	81
55530	2010-11-30 01:00:00Z	2010-11-30 07:38:00Z	131	30	90	0	0	25	25	57	27	27	131	30	0	0	0	0	0	0	0	0
55531	2010-12-01 03:45:00Z	2010-12-01 07:19:17Z	59	0	60	0	0	3	20	18	13	5	59	0	0	0	0	0	0	0	0	0
55532	2010-12-02 02:30:00Z	2010-12-02 08:23:55Z	34	41	44	0	0	17	10	48	0	0	60	5	0	1	2	3	1	0	0	3
55533	2010-12-03 02:00:00Z	2010-12-03 08:20:21Z	92	60	75	0	0	50	44	58	0	0	33	2	107	2	2	2	0	2	0	2
55534	2010-12-04 01:25:00Z	2010-12-04 08:17:06Z	158	44	104	0	0	55	51	42	27	27	0	2	189	3	0	3	0	2	0	3
55535	2010-12-05 00:39:04Z	2010-12-05 08:12:36Z	128	145	112	0	0	108	90	75	0	0	254	4	0	2	0	5	0	4	0	4
55536	2010-12-06 01:00:00Z	2010-12-06 06:49:46Z	207	0	86	0	0	73	68	66	0	0	0	207	0	0	0	0	0	0	0	0
55537	2010-12-07 00:40:49Z	2010-12-07 08:05:09Z	150	41	115	0	0	47	43	36	35	30	18	18	0	141	0	7	0	3	0	4
55538	2010-12-08 00:41:40Z	2010-12-08 08:03:44Z	225	28	110	0	0	118	116	19	0	0	102	4	0	4	58	59	1	20	1	4
55539	2010-12-09 00:42:30Z	2010-12-09 07:41:04Z	257	0	101	0	0	108	109	40	0	0	71	0	0	0	0	4	73	53	46	10
55540	2010-12-10 00:43:19Z	2010-12-10 07:53:39Z	132	132	112	0	0	104	99	61	0	0	90	15	1	5	7	9	7	2	87	41
55541	2010-12-11 00:44:06Z	2010-12-11 05:52:52Z	52	50	50	0	0	77	20	5	0	0	19	6	0	13	5	14	1	4	1	39
55542	2010-12-12 00:44:52Z	2010-12-12 06:46:45Z	94	91	78	0	0	107	41	3	7	27	25	125	2	1	0	27	0	1	1	3
55543	2010-12-13 00:45:37Z	2010-12-13 06:42:50Z	77	36	86	0	0	21	47	18	0	27	0	53	11	3	1	2	14	27	2	0
55544	2010-12-14 00:46:20Z	2010-12-14 05:41:05Z	92	24	77	0	0	30	37	25	1	23	0	37	16	3	24	13	0	0	10	13

Credit: E. Neilsen